Nos. 2015-1425, -1438

United States Court of Appeals for the Federal Circuit

RUCKUS WIRELESS, INC., CISCO SYSTEMS, INC.,

Plaintiffs-Appellees,

v.

INNOVATIVE WIRELESS SOLUTIONS, LLC,

Defendant-Appellant,

Appeals from the United States District Court for the Western District of Texas in Nos. 1:13-cv-00492-LY and 1:13-cv-00504-LY, Judge Lee Yeakel

BRIEF OF DEFENDANT-APPELLANT INNOVATIVE WIRELESS SOLUTIONS, LLC

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May 11, 2015

CERTIFICATE OF INTEREST

1. The full name of every party represented by me is:

   Innovative Wireless Solutions, LLC.

2. There are no other real parties in interest represented by me.

3. Innovative Wireless Solutions, LLC certifies that it has no corporate parent and there are no publicly held corporations that own 10% or more of its stock.

4. The names of all the firms or lawyers that appeared for the party now represented by me in the trial court or are expected to appear in this court are as follows:

   Jonathan D. Baker, Steven R. Daniels, and Michael D. Saunders of Farney Daniels, PC

   Stephanie Wood, formerly of Farney Daniels, PC

Dated: May 11, 2015

/s/ *Jonathan D. Baker*
Jonathan D. Baker

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STATEMENT OF RELATED CASES

No other appeal in or from the same civil action or proceeding in the lower court or body was previously before this or any other appellate court. No other case is known to counsel for Appellant Innovative Wireless Solutions, LLC to be pending in this or any other court that will directly affect or be directly affected by this court's decision in these pending appeals.

JURISDICTIONAL STATEMENT

This is an appeal from the United States District Court for the Western District of Texas' stipulated final judgment (A1-2, attached as Addendum A) that Plaintiffs do not infringe U.S. Patent Nos. 5,912,895 ("the '895 Patent"), 6,327,264 ("the '264 Patent"), and 6,587,473 ("the '473 Patent") (A44-66, A67-85, and A86-108, attached as Addendums C, D, and E respectively), and from the district court's Memorandum Opinion and Order Regarding Claims Construction (A3-43, attached as Addendum B) which was the basis of the stipulated judgment of non-infringement. Innovative Wireless Solutions, LLC has timely filed notices of appeal, and this Court has jurisdiction pursuant to 28 U.S.C. § 1295(a)(1). A1356-59.

STATEMENT OF THE ISSUES

1. Whether the district court erred in construing the phrases "bidirectional communications path" and "communications path" in the '895, '264, and '473 Patents as a "[bidirectional] communications path utilizing twisted-pair wiring that is too long to permit conventional 10BASE-T or similar LAN (Local Area Network) interconnections."

STATEMENT OF THE CASE

I. BACKGROUND OF THE PATENTS AND THE TECHNOLOGY

Defendant-Appellant Innovative Wireless Solutions, LLC ("IWS") owns all right, title, and interest to U.S. Patent Nos. 5,912,895 ("the '895 Patent"), 6,327,264 ("the '264 Patent"), and 6,587,473 ("the '473 Patent") (collectively, the "patents-in-suit"). A44-66, A67-85, and A86-108 (attached as Addendums C, D, and E respectively).

The inventors of the patents-in-suit were focused on the mid-1990s goal of increasing access to high-speed Internet. As the patents describe, in 1996 when the first application was filed, "[c]omputers and related devices [we]re increasingly being connected into networks between the devices," which "resulted in a global information network which is generally known as the Internet." A53 ('895 Pat. at 1:13-24.).[1] Connecting to the Internet "typically" involved various layers of networks, such as "LANs (local area networks) which provide communications among devices within a relatively small geographic area," and "different LANs being interconnected via MANs (metropolitan area networks) and WANs (wide area networks)." *Id.* at 1:15-19. The inventors realized that the increasing number of devices, including "general-purpose computers," "[n]etwork browser[s], game machine[s]," "entertainment device[s]," "workstations, printers, scanners, bridges,

[1] Each of the patents-in-suit shares a substantially identical specification. Thus, for consistency, all citations to the specification herein are to the specification of the '895 Patent.

routers, etc." "may be desired to connect to the Network" of the Internet through existing LANs. *Id.* at 2:24-30.

One of the "most common" technologies for LANs at the time was "CSMA/CD, or Carrier Sense Multiple Access with Collision Detection technology." A53 ('895 Pat. at 1:25-28). In particular, the patents discuss at length "Ethernet" or the "IEEE Standard 802.3," the predominant form of CSMA/CD technology. *Id.* at 1:28-45. As described in the IEEE 802.3 Standard discussed in the patents-in-suit, CSMA/CD technology was originally created and used for connecting network devices to a communication channel where potentially more than one device could be transmitting at the same time. A53, A56 ('895 Pat at 1:25-45, 7:66-8:22); A980, A990. If two devices communicated on the channel at the same time (or at least overlapped) the transmissions could become garbled, a condition known as a collision. *Id.*; A943 § 3.143. As the patents explain, under CSMA/CD, a device that wishes to transmit on the network listens and checks to see if the channel is free for sending data. A56 ('895 Pat. at 8:8-9). If the network line is free and the device starts transmitting, it still monitors the line for collisions caused by another device attempting to transmit at the same time. *Id.* at 8:10-12. If the channel is not free, or if a collision is detected during transmission, the transmitting device waits for a small amount of time and tries the whole process again. *Id.* at 8:15-18.

Although CSMA/CD technology was both "common" and flexible—allowing devices to be added and removed from the network freely (A53 ('895 Pat. at 1:61-2:18))—the patents-in-suit acknowledge that CSMA/CD "can not be used"

over all transmission media. *Id.* at 2:38-42. For example, CSMA/CD could not work over some transmission media because of "performance specifications, in particular a maximum delay" (*id.* at 2:6-7), "propagation delay" (A56 ('895 Pat. at 8:31-35)), or "signal attenuation" (*id.* at 8:35-38). Thus, the problem that the patents-in-suit addressed was providing an Internet connection to devices connected to a CSMA/CD network, over a medium where CSMA/CD may be unsuitable.

The solution developed by the inventors, as reflected in the language used by most of the claims, generally relates to using to a device which couples a "CSMA/CD interface" to another communications path, and controlling communications over the "communications path" using certain "control information" so that the communications via the communications path take place in a "half duplex" manner. *See, e.g.* A65 ('895 Pat., cl. 48). Various additional techniques for managing and organizing the communications are also recited in the claims. Claim 5 of the '264 Patent is exemplary, and recites:

> 5. Network access apparatus comprising:
>
> a CSMA/CD (Carrier Sense Multiple Access with Collision Detection) interface for coupling to a CSMA/CD path;
>
> a second interface for coupling to a bidirectional communications path;
>
> a control unit for producing control information for controlling another apparatus coupled to the communications path so that communications via the communications path take place in a half duplex manner;
>
> a first buffer arranged to buffer information packets received from the CSMA/CD path via the CSMA/CD interface and to supply buffered information packets via the second interface to the communications path; and

> a second buffer arranged to buffer information packets received from the communications path via the second interface and to supply buffered information packets to the CSMA/CD path via the CSMA/CD interface.

A85 ('264 Pat., cl. 5).

The Nortel engineers who invented the patents-in-suit, working at a telecom company, described the preferred embodiments of their invention in the context of "a two-wire telephone line." A44, A53 ('895 Pat. at 2:33-40). However, the claims reflect a wide variety of embodiments, including, both embodiments expressly limited to "two-wire telephone lines," as well as embodiments instead using the more general term "communications path." *See, e.g.*, A63-65 ('895 Pat., cls. 1, 42). Additionally, the specification never describes the problems that the patents were meant to address—providing a high-speed Internet connection to CSMA/CD networks over a network path unsuitable for CSMA/CD—as being exclusively unique to two-wire telephone lines, or even wired lines in general. Nor does the specification expressly state that wireless embodiments are outside the scope of the invention. Indeed, the inventors instead expressly acknowledged that the descriptions in the specification were only "particular embodiments of the invention" and that "it should be appreciated that numerous other modifications, variations, and adaptations may be made without departing from the scope of the invention as defined in the claims." A62-63 ('895 Pat. at 20:66-21:3).

II. HISTORY OF THE CASES IN THE DISTRICT COURT

These appeals arise from declaratory judgment lawsuits filed by Plaintiff-Appellees Ruckus Wireless, Inc. ("Ruckus") and Cisco Systems, Inc. ("Cisco")

against IWS in the Western District of Texas, asserting claims for declaratory judgment of non-infringement and invalidity of the patents-in-suit. A109-121, A283-295. IWS filed counterclaims for infringement of the patents-in-suit against Cisco and Ruckus. A457-496.

The district court set a consolidated pre-trial schedule and *Markman* hearing for the Ruckus and Cisco cases. A518. The parties thereafter exchanged infringement and invalidity contentions. A526, A1350 ¶ 4. In its infringement contentions, IWS alleged that Cisco and Ruckus products that are compliant with the IEEE 802.11 g, n, and/or ac standards, such as wireless base stations, access points, and routers, infringed claims 1-12, 15-20, 27-37, 40, 48, 49, 51-53 of the ’895 Patent, claims 5-9 of the ’264 Patent, and claims 1-5, 7-20, 22-26, 29-42 of the ’473 Patent. A466-474, A486-494, A1350 ¶ 4.

Subsequently, the parties submitted a joint claim construction chart and simultaneous opening and reply claim construction briefs. A619-622, A625-27, A655-658, A661-663, A691-A710, A865-872, A877-880, A1014-1023, A1103-A1119. Among the terms disputed by the parties were the terms “communications path” and “bidirectional communications path”—one of which appears in each asserted claim of the patents-in-suit. A625, A661. Cisco and Ruckus asserted that both of the terms should be construed as “a wired communications path for exchanging information between two endpoints.” A705. IWS argued that the terms should be given their ordinary meaning and need not be further construed. A877. However, IWS noted that “bidirectional” could be construed as “[c]apable of transmission in either or both directions,” and that the “ordinary meaning of

communications path" is simply "a path upon which communications take place." A1110.

The district court held a *Markman* hearing on May 28, 2014, and issued its Memorandum Opinion and Order Regarding Claims Construction on January 8, 2015, construing twenty terms or groups of related terms of the patents-in-suit. A4, A38-43. The district court construed "communications path" as a "communications path utilizing twisted-pair wiring that is too long to permit conventional 10BASE-T or similar LAN (Local Area Network) interconnections" and "bidirectional communications path" as a "bidirectional communications path utilizing twisted-pair wiring that is too long to permit conventional 10BASE-T or similar LAN interconnections." A39. In particular, the district court found that the patents-in-suit "are solely focused on communicating information packets long distances over wired communication paths" and that "[t]he repeated reference to two-wire lines and telephone lines emphasizes that the inventor was focused on this transmission medium as the core of the new technology." A20. Additionally, the district court focused on a single passage of the specification and found that it "identifies the protocol that lies at the heart of the invention" and "makes it clear that the patents' scope is limited to a communication path between modems consisting of twisted-pair wiring that is too long to permit conventional LAN interconnections." A20-21 (citing '895 Pat. at 9:32-10:8 (A57)).

The parties subsequently entered into a stipulation for entry of final judgment of non-infringement, and to dismiss all other claims, counterclaims, and defenses without prejudice "in light of the Court's Memorandum Opinion and

Order Regarding Claims Construction." A1351-55. In particular, the parties stipulated that "the accused communications path associated with each Accused Product" "is not wired" and does not "utiliz[e] twisted-pair wiring." A1350-51 ¶ 6. The stipulation further explained that "each Accused Product contains one or more radio transceivers (in connection with other circuitry) for communicating wirelessly with devices that are compliant with the IEEE 802.11 (g), (n) and/or (ac) protocols and IWS's infringement contentions identify those wireless communications as satisfying the 'bidirectional communications path' and 'communications path' limitations." *Id.* The stipulation expressly provided that it was "[s]ubject to all of IWS's rights to appeal." A1351 ¶ 7. The stipulation also provided for dismissal of "all other claims and defenses" "subject to IWS, Cisco and Ruckus's right to revive any such claim, counterclaim, and/or defenses, in the event of a remand from the Federal Circuit Court of Appeals." A1351 ¶ 9. The district court thereafter approved the parties' stipulation and entered the stipulated final judgment of non-infringement. A1-2.

SUMMARY OF THE ARGUMENT

In construing the terms "communications path" and "bidirectional communications path," the district court erred by violating a cardinal rule of claim construction—the court imported into the claim language of the patents-in-suit limitations from a preferred embodiment disclosed in the specification. Specifically, the district court interpreted these terms to require that the communications path "utilize[e] twisted-pair wiring that is too long to permit conventional 10BASE-T or similar LAN (Local Area Network) interconnections."

The plain language of the claims and the specification, however, make clear that the asserted claims are not limited to wired lines. Thus, this Court should overrule the district court's claim construction, construe "communications path" as having its ordinary meaning, vacate the judgment and remand for further proceedings.

ARGUMENT

I. STANDARD OF REVIEW

"In reviewing questions of claim construction," this Court "review[s] underlying factual determinations for clear error and ultimate determinations de novo." *Cadence Pharms., Inc. v. Exela PharmSci Inc.*, 780 F.3d 1364, 1368 (Fed. Cir. 2015) (*citing Teva Pharm. USA, Inc. v. Sandoz, Inc.*, 135 S. Ct. 831, 841, 190 L. Ed. 2d 719 (2015) (claim construction)). "When the district court reviews only evidence intrinsic to the patent . . . , the judge's determination will amount solely to a determination of law, and [this Court will] review that construction de novo." *Id.*; *MobileMedia Ideas LLC v. Apple Inc.*, 780 F.3d 1159, 1180 (Fed. Cir. 2015) ("because the district court's construction relies only on intrinsic evidence, we review its construction de novo.").

In this case, the decision of the district court in construing the phrases "communications path" and "bidirectional communications path" was based entirely on intrinsic evidence. A38-43. Therefore, the appropriate standard of review is *de novo*.

II. LAW OF CLAIM CONSTRUCTION

It is a "bedrock principle" of patent law that the claims of a patent define the invention, and not its specification. *Phillips v. AWH Corp.*, 415 F.3d 1303, 1312

(Fed. Cir. 2005). Accordingly, when determining the scope of the invention, "the analytical focus must begin and remain centered on" the language of the claims. *Gillette Co. v. Energizer Holdings, Inc.*, 405 F.3d 1367, 1370 (Fed. Cir. 2005). In particular, other claims of the same patent can be "valuable sources of enlightenment" as to the meaning of a claim term. *Phillips*, 415 F.3d at 1314. Of course, the claims are "read in view of the specification, of which they are a part." *Id.* at 1315. Generally, however, it is a "cardinal sin" to read a limitation from the specification into the claims. *Id.* at 1320. Rather, a claim term should be given "its broadest ordinary meaning consistent with the written description." *Int'l Rectifier Corp. v. IXYS Corp.*, 361 F.3d 1363, 1373-74 (Fed. Cir. 2004).

"The patentee is free to choose a broad term and expect to obtain the full scope of its plain and ordinary meaning unless the patentee explicitly redefines the term or disavows its full scope." *Thorner v. Sony Computer Entm't Am. LLC*, 669 F.3d 1362, 1367 (Fed. Cir. 2012). "To act as its own lexicographer, a patentee must clearly set forth a definition of the disputed claim term other than its plain and ordinary meaning." *Id.* (citations and quotations omitted). "It is not enough for a patentee to simply disclose a single embodiment or use a word in the same manner in all embodiments, the patentee must clearly express an intent to redefine the term." *Id.* (citations and quotations omitted). "The standard for disavowal of claim scope is similarly exacting"—"[t]he patentee may demonstrate intent to deviate from the ordinary and accustomed meaning of a claim term by including in the specification expressions of manifest exclusion or restriction, representing a clear disavowal of claim scope." *Id.* at 1366 (citations and quotations omitted). "It

is [] not enough that the only embodiments, or all of the embodiments, contain a particular limitation." *Id.*

III. THE DISTRICT COURT ERRONEOUSLY CONSTRUED THE PHRASES "COMMUNICATIONS PATH" AND "BIDIRECTIONAL COMMUNICATIONS PATH"

The district court erroneously construed the phrases "communications path" and "bidirectional communications path." A39. The district court did not premise its construction on the "plain and ordinary meaning" of the words "communications" or "path," nor did it even purport to analyze their ordinary meaning. A18-22. Instead, the district court's construction imported additional limitations based on the disclosures of the specification. Indeed, the district court's construction for these terms verbatim repeats the claim term itself, and then adds the additional language "utilizing twisted-pair wiring that is too long to permit conventional 10BASE-T or similar LAN (Local Area Network) interconnections." A22.

Rather than relying on the plain and ordinary meaning, the district court explained that its construction was based on "consideration of the entire specification," "[t]he repeated reference to two-wire lines and telephone lines," and a particular passage of the specification which the district court characterized as "identif[ying] the protocol that lies at the heart of the invention and forms the basis of the patented technology." A20. In particular, the district court placed great weight on the passage from the "Detailed Description" section of the specification which stated that: "Thus although as described here the line 12 is a telephone subscriber line, it can be appreciated that the same arrangement of master and slave

modems operating in accordance with this new protocol can be used to communicate Ethernet frames via any twisted pair wiring which is too long to permit conventional 10BASE-T or similar LAN interconnections." A20-21 (citing '895 Pat. at 9:32-10:8 (A57)).

This reasoning is plainly contrary to this Court's precedent on claim construction. The district court's reliance on "[t]he repeated reference to two-wire lines and telephone lines" violates this Court's holding that "'[i]t is [] not enough' to constitute a disavowal 'that the only embodiments, or all of the embodiments, contain a particular limitation.'" *Thorner*, 669 F.3d 1362 at 1366. Additionally the language "the same arrangement of master and slave modems . . . can be used to communicate . . . via any twisted pair wiring which is too long to permit conventional 10BASE-T or similar LAN interconnections" is evidently words of *inclusion*, not words of "manifest exclusion or restriction" required to constitute a disavowal. *Id.* That is, this passage states what "can be used to communicate" with an "arrangement of master slave modems," not what *cannot* be used to communicate, or what *must* be used to communicate.

Moreover, this passage does not even recite the claim term at issue—"communications path." Instead, the passage is merely describing the modems of Figure 3 of the specification—which "illustrates a Network access arrangement in accordance with an *embodiment* of this invention." A55 ('895 Pat. at 6:44-45 (emphasis added)), A56-57 ('895 Pat. at 8:44-10:14 (describing Figure 3)). Furthermore, many of the asserted claims which recite the claimed "communications path" do not even recite any "modems" at all, little less the

"modems" of this "embodiment" that the district court found to be a clear disavowal. *See, e.g.* A63, A65 ('895 Pat., cls. 1, 48); A85 ('264 Pat., cls. 5, 8), A107 ('473 Pat., cl. 30).

Indeed, the erroneousness of the district court's construction is further demonstrated by this Court's recent decision in *Hill-Rom Servs. v. Stryker Corp.*, 755 F.3d 1367 (Fed. Cir. 2014) which concerned whether the claim term "datalink" should be limited to a wired connection. In *Hill-Rom*, the district court construed the term "datalink" to be limited to "a cable connected to the bed that carries data." *Id.* at 1371. In that case, "the specifications of the patents-in-suit use the terms 'datalink 39,' 'cable 39,' and 'serial datalink 39' to describe the same component of the preferred embodiment." *Id.* at 1373. In addition, in *Hill-Rom*, this Court noted that the "disclosed embodiment undisputedly uses a cable to convey data, and the patent does not disclose an alternative embodiment that uses a wireless datalink." *Id.*

Nonetheless, this Court concluded in *Hill-Rom* that the term "datalink" was not limited to wired embodiments. The Court held that "to deviate from the plain and ordinary meaning of a claim term to one of skill in the art, the patentee must, with some language, indicate a clear intent to do so in the patent." *Id.* Thus, the Court concluded, "absent some language in the specification or prosecution history suggesting that the wired connection is important, essential, necessary, or the 'present invention,' there is no basis to narrow the plain and ordinary meaning of the term datalink to one type of datalink—a cable." *Id.* In addition, the Court noted that the figures for the "datalink" were described as "illustrat[ing]

embodiments of the invention" and that the patent recited the language that "the 'description of various embodiments' is not intended 'to restrict or in any way limit the scope of the appended claims to such detail." *Id.*

The similarities of the present case to *Hill-Rom* are striking. Like the defendant in *Hill-Rom*, Cisco and Ruckus do "not dispute that wireless [communications paths] were known at the time the patent was filed, nor does it suggest that the plain meaning of [communications path] at the relevant time was a" twisted-pair wiring. *Id.* at 1374. As in *Hill-Rom*, the specification recites a disclaimer emphasizing that the descriptions of the specification are merely "particular embodiments of the invention" and are not restrictive. A62-63 ('895 Pat. at 20:66-21:3). Like *Hill-Rom*, the figure of the specification discussed in the passage on which the district court relied is described as merely "illustrat[ing] . . . an embodiment." A55 ('895 Pat. at 6:44-45). Finally, like *Hill-Rom*, nothing in the specification of the patents-in-suit states that "twisted-pair wiring" is essential or necessary, nor does it describe such wiring as being part of the "present invention."

Thus, the district court's construction of "communications path" and "bidirectional communications path" are erroneous under this Court's precedent. This Court should instead determine that "communications path" is not limited to any wired embodiment and should instead be accorded its ordinary meaning. The Court may rely on a term's ordinary meaning "if the court resolves the parties' claim-scope dispute and precludes the parties from presenting jury arguments inconsistent with the court's adjudication of claim scope." *See ActiveVideo*

Networks v. Verizon Communications, 694 F.3d 1312, 1325-26 (Fed. Cir. 2012) (holding that an ordinary meaning construction is appropriate where the dispute concerns whether a limitation from the specification should be imported into the claims).

IV. THE INTRINSIC RECORD SUPPORTS A CONSTRUCTION OF "COMMUNICATIONS PATH" THAT IS NOT LIMITED TO WIRED CONNECTIONS

Not only does the intrinsic record fail to include a disavowal of communications paths other than wired connections, the claim language itself shows that the term "communications path" should be construed to have its plain and ordinary meaning. For example, independent claim 1 of the '895 Patent recites "A method of providing communications with a CSMA/CD … network via a bidirectional communications path," and independent claim 48 recites "A network access arrangement for providing communications with a CSMA/CD … path via a communications path." A63 ('895 Pat. cl. 1, at 21:5-7, 25:52-54). Similarly, independent claims 5 and 8 of the '264 patent and independent claims 1, 11, 26, 30, 35, and 40 of the '473 Patent all recite "a communications path" or "a bidirectional communications path" without further limitation on the type of path. A85, A105-108. Thus, although each of the asserted claims recites a variety of different components and configurations, none recite any "wired" limitation, little less a "twisted-pair wiring that is too long to permit conventional 10BASE-T or similar LAN (Local Area Network) interconnections."

By contrast, independent claim 42 of the '895 Patent recites "a two-wire telephone subscriber line" in lieu of reciting a communications path. A65 ('895

Pat. cl. 42, at 25:3-6). Similarly, independent claims 56 and 71 of the ’895 Patent recite “a two-wire line.” *Id.* at 26:51-52, 28:28-30. Further, independent claims 1 and 3 of the ’264 Patent recite, “wherein the communications path comprises a two-wire telephone subscriber line.” A85 (’264 Pat. at 19:27-28 and 62-63). Thus, the patentee intentionally limited certain claims to the wired communication path of the preferred embodiment, while drafting other claims broadly to cover any type of communication path. Likewise, dependent claims 13, 21, 23, and 25 of the ’895 Patent and dependent claims 6, 21, 27, and 28 of the ’473 Patent also recite the “two-wire line” limitation. A63-64 (‘895 Pat. at 22:24-33, 23:1-10, 16-26, and 32-41), A105-107 (’473 Pat. at 20:12-13, 22:13-15, and 23:12-19). Indeed, claim 6 of the ’473 Patent merely claims, in its entirety, “6. A method as claimed in claim 1, wherein the bidirectional communications path comprises a two-wire line.” A105 (’473 Pat. at 20:12-13). Thus, the claims explicitly contemplate that “communications path” is broader than a “two-wire line.” *See Phillips*, 415 F. 3d at 1315 (“the presence of a dependent claim that adds a particular limitation gives rise to a presumption that the limitation in question is not present in the independent claim”). Given that a twisted-pair line necessarily has two wires, the district court’s construction is inconsistent with the teaching of the claims.

Moreover, the specification also teaches that the “communications path” is broader than the wired embodiment of the district court’s construction. In particular, the specification teaches that:

> It is known to provide for access to the Network from a relatively distant terminal device, or TD, via a communications path

> between a router on the Network and the distant TD, the communications path *typically* being constituted by a telephone line.
>
> *A simple form of such a communications path* is a serial link comprising modem communications via a conventional two-wire telephone line.

A53 ('895 Pat. at 2:33-41 (emphasis added)). This passage plainly discusses the relationship between the "communications path" and the two-wire telephone embodiment with words of inclusion rather than exclusion. The suggestion that the "communications path" is "*typically*" a telephone line suggests that "communications path" is broader than telephone lines. Similarly, describing a "serial link comprising modem communications via a conventional two-wire telephone line" as a "simple form of such a communications path" also suggests that arrangements other than the described two-wire telephone lines can constitute a "communications path." Furthermore, this portion of the specification is plainly more pertinent to the construction of "communications path" than the portion relied on by the district court because this portion actually discusses a "communications path" unlike the portion relied upon by the district court. Thus, although the preferred embodiment of the patents uses a twisted-pair, two-wire telephone line, the patent itself acknowledges that the communications path can be broader than that embodiment and does not disavow such other communications paths from the scope of the claims.

Additionally, the "Summary of the Invention" section of the specification also indicates that the "communications path" is broader than the two-wire, twisted-pair line of the preferred embodiment. The "Summary of the Invention" sets forth various distinct embodiments of the invention, many of which are

described as using the two-wire, twisted pair preferred embodiment. However, one of the embodiments described in the Summary of the Invention, at Column 4, line 37 through Column 5, line 21 of the ’895 Patent, describes the embodiment using language which does not mention any wired connection at all:

> Another aspect of the invention provides a method of providing communications with a CSMA/CD network via a bidirectional *communications path*, comprising the steps of: at a first end of the *communications path*, providing a CSMA/CD interface to the network, buffering information packets received from the network via the interface in a first buffer, supplying information packets from the first buffer to the *communications path*, and supplying control information to the *communications path*; at a second end of the *communications path*, buffering information packets received via the *communications path* in a second buffer, receiving the control information from the *communications path*, buffering information packets to be supplied via the *communications path* to the network in a third buffer, and supplying information packets from the third buffer to the *communications path* in dependence upon the control information; and at the first end of the *communications path*, supplying information packets received via the *communications path* to a fourth buffer, and supplying the information packets from the fourth buffer to the network via the interface; wherein the control information and the dependence on the control information for supplying information packets from the third buffer to the *communications path* are arranged to avoid collisions on the *communications path* between information packets communicated from the first buffer to the second buffer and information packets communicated from the third buffer to the fourth buffer.
>
> . . .
>
> Preferably in this method the information packets are communicated via the *communications path* as modulated signals between modems at the first and second ends of the *communications path*.
>
> . . .
>
> This method can further comprise the steps of providing a second CSMA/CD interface to a second CSMA/CD path at the second end of the *communications path* and communicating information packets

> between the second and third buffers and the second CSMA/CD path via the second CSMA/CD interface.

A54 ('895 Pat. at 4:37-5:21 (emphasis added)). Including the description of an embodiment which repeatedly discusses the "communications path" without mentioning it being wired strongly suggests that the inventors intended to embrace the ordinary meaning of "communications path"—one not limited to a wired embodiment.

CONCLUSION AND STATEMENT OF RELIEF SOUGHT

For the foregoing reasons, IWS respectfully requests that this Court find that the district court erred in construing the terms "communications path" and "bidirectional communications path," hold that the construction of those terms should be governed by their ordinary meaning, and vacate the judgments and remand the cases to the district court for further proceedings.

Dated: May 11, 2015

Respectfully submitted,

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ADDENDUMS

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ADDENDUM A

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IN THE UNITED STATES DISTRICT COURT
FOR THE WESTERN DISTRICT OF TEXAS

CISCO SYSTEMS, INC., Plaintiff, vs. INNOVATIVE WIRELESS SOLUTIONS, LLC, Defendant.	Case No. 1:13-cv-00492-LY
RUCKUS WIRELESS, INC., Plaintiff, vs. INNOVATIVE WIRELESS SOLUTIONS, LLC, Defendant.	Case No. 1:13-cv-00504-LY

[redacted] FINAL JUDGMENT OF NON-INFRINGEMENT

Before the Court is the Joint Stipulation For Entry Of Final Judgment Of Non-Infringement filed by Plaintiffs Cisco Systems, Inc. ("Cisco") and Ruckus Wireless, Inc. ("Ruckus") and Defendant Innovative Wireless Solutions, LLC ("IWS") in the above cases. Based on the stipulation of the parties, and good cause appearing, the parties' joint stipulation is APPROVED and SO ORDERED. Accordingly, IT IS HEREBY ORDERED, ADJUDGED AND DECREED THAT:

1. Final Judgment of Non-Infringement of U.S. Patent Nos. 5,912,895; 6,327,264; and 6,587,473 (collectively, the "Patents-in-Suit") is entered for declaratory judgment plaintiffs Cisco and Ruckus and against declaratory judgment defendant IWS on: (i) Cisco's and Ruckus's claims for a declaratory judgment of non-infringement, (ii) IWS's counterclaims for

infringement of the Patent-in-Suit, and (iii) IWS's Second, Fourth and Sixth Affirmative Defenses; and

2. All other claims, counterclaims, defenses, or other matters which have been asserted (except for any claim(s) or motion(s) relating to an "exceptional case" determination pursuant to 35 U.S.C. § 285 or other bases for the award of attorneys' fees and/or costs, the timing of which is governed by Fed. R. Civ. P. 54(d)(1) and (2), and Fed. R. Civ. P. 58(e)) are hereby DISMISSED WITHOUT PREJUDICE.

Dated: March 3, 2015.

The Honorable Lee Yeakel
United States District Court

ADDENDUM B

IN THE UNITED STATES DISTRICT COURT
FOR THE WESTERN DISTRICT OF TEXAS
AUSTIN DIVISION

CISCO SYSTEMS, INC.,
PLAINTIFF,

V.

INNOVATIVE WIRELESS SOLUTIONS, LLC,
DEFENDANT.

CAUSE NO. 1:13-CV-00492-LY

RUCKUS WIRELESS, INC.,
PLAINTIFF,

V.

INNOVATIVE WIRELESS SOLUTIONS, LLC,
DEFENDANT.

CAUSE NO. 1:13-CV-00504-LY

MEMORANDUM OPINION AND ORDER REGARDING CLAIMS CONSTRUCTION

Before the court are the parties' Joint Claim Construction Statement filed January 13, 2014 (Clerk's Doc. No. 36)[1] and Supplemental Claim Construction Statement filed February 21, 2014 (Clerk's Doc. No. 41); Plaintiffs' Opening Claim Construction Brief filed March 4, 2014 (Clerk's Doc. No. 44); Defendant's Opening Claim Construction Brief filed March 4, 2014 (Clerk's Doc. No. 45); Plaintiffs' Reply Claim Construction Brief filed April 2, 2014 (Clerk's Doc. No. 46); Defendant's Response to Plaintiffs' Opening Claim Construction Brief filed April 2, 2014 (Clerk's Doc. No. 47); Plaintiffs' Supplemental Claim Construction Brief Regarding Indefiniteness Issues

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[1] At an August 28, 2013 pretrial conference, the court consolidated these cases for pretrial purposes. Although parallel filings were made in both cases, unless otherwise noted, this order uses docket reference numbers from cause number 1:13-CV-00492-LY. The constructions set forth in this order apply in both cases.

filed July 3, 2014 (Clerk's Doc. No. 57); Defendant's Response to Plaintiffs' Supplemental Claim Construction Brief Regarding Indefiniteness Issues filed July 17, 2014 (Clerk's Doc. No. 58); Defendant's Notice of Supplemental Authority Regarding the Federal Circuit's Opinion in *Hill-Rom Servs. v. Stryker Corp* filed July 17, 2014 (Clerk's Doc. No. 59); Plaintiffs' Response to Defendant's Notice of Supplemental Authority filed August 8, 2014 (Clerk's Doc. No. 60), and the claim construction presentations of the parties.

The court held a claim-construction hearing on May 28, 2014. *See Markman v. Westview Instruments, Inc.*, 52 F.3d 967, 976 (Fed. Cir. 1995) (*en banc*), *aff'd*, 517 U.S. 370 (1996). After considering the patents and their prosecution history, the parties' claim-construction briefs and additional filings, the applicable law regarding claim construction, and argument of counsel, the court now renders its order with regard to claim construction.

1. Introduction

The court renders this memorandum opinion and order to construe the claims in U.S. Patents No. 5,912,895 (the "'895 Patent"), 6,327,264 (the "'264 Patent"), and 6,587,473 (the "'473 Patent") (collectively, the "patents-in-suit" or the "Terry patents"). The '473 Patent is a continuation of the '264 Patent, which is a continuation of the '895 Patent. All patents share a common specification and drawings. The patents-in-suit generally relate to a method for communicating information packets over long distances.

Plaintiffs Cisco Systems, Inc. ("Cisco") and Rukus Wireless, Inc. ("Rukus")[2] seek declaratory judgment against Defendant Innovative Wireless Solutions, LLC ("Innovative Wireless"). Cisco asserts that the patents-in-suit are not infringed and are invalid. *See* 28 U.S.C. §§ 2201, 2202.

2. Legal Principles of Claim Construction

Determining infringement is a two-step process. *See Markman,* 52 F.3d at 976 ("[There are] two elements of a simple patent case, construing the patent and determining whether infringement occurred . . . ."). First, the meaning and scope of the relevant claims must be ascertained. *Id.* Second, the properly construed claims must be compared to the accused device. *Id.* Step one, claim construction, is the current issue before the court.

The court construes patent claims without the aid of a jury. *See Markman* 52 F.3d at 979. The "words of a claim 'are generally given their ordinary and customary meaning.'" *Phillips v. AWH Corp.*, 415 F.3d 1303, 1312 (Fed. Cir. 2005) (*en banc*) (quoting *Vitronics Corp. v. Conceptronic, Inc.*, 90 F.3d 1576, 1582 (Fed. Cir. 1996)). The ordinary and customary meaning of a claim term is the meaning that the term would have to a person of ordinary skill in the art in question at the time of the invention. *Id.* at 1313. The person of ordinary skill in the art is deemed to have read the claim term in the context of the entire patent. *Id.* Therefore, to ascertain the meaning of claims, courts must look to the claims, the specification, and the patent's prosecution history. *Id.* at 1314–17; *Markman*, 52 F.3d at 979.

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[2] As the arguments and interests of Plaintiffs Cisco Systems, Inc. and Ruckus Wireless, Inc. do not diverge with regard to claim construction, the court will refer to Plaintiffs collectively as "Cisco."

Claim language guides the court's construction of claim terms. *Phillips*, 415 F.3d at 1314. "[T]he context in which a term is used in the asserted claim can be highly instructive." *Id.* Other claims, asserted and unasserted, can provide additional instruction because "terms are normally used consistently throughout the patent." *Id.* Differences among claims, such as additional limitations in dependent claims, can provide further guidance. *Id.*

Claims must also be read "in view of the specification, of which they are a part." *Markman*, 52 F.3d at 979. The specification "is always highly relevant to the claim construction analysis. Usually, it is dispositive; it is the single best guide to the meaning of a disputed term." *Teleflex, Inc. v. Ficosa N. Am. Corp.*, 299 F.3d 1313, 1325 (Fed.Cir.2002) (internal citations omitted). In the specification, a patentee may define a term to have a meaning that differs from the meaning that the term would otherwise possess. *Phillips*, 415 F.3d at 1316. In such cases, the patentee's lexicography governs. *Id.* The specification may also reveal a patentee's intent to disclaim or disavow claim scope. *Id.* Such intentions are dispositive for claim construction. *Id.* Although the specification may indicate that certain embodiments are preferred, particular embodiments appearing in the specification will not be read into the claims when the claim language is broader than the embodiment. *Electro Med. Sys., S.A. v. Cooper Life Scis., Inc.*, 34 F.3d 1048, 1054 (Fed. Cir. 1994).

The prosecution history is another tool to supply the proper context for claim construction because it demonstrates how the inventor understood the invention. *Phillips*, 415 F.3d at 1317. A patentee may serve as his own lexicographer and define a disputed term in prosecuting a patent. *Home Diagnostics, Inc. v. LifeScan, Inc.*, 381 F.3d 1352, 1356 (Fed.Cir.2004). Similarly, distinguishing the claimed invention over the prior art during prosecution indicates what the claims do not cover. *Spectrum Int'l v. Sterilite Corp.*, 164 F.3d 1372, 1378–79 (Fed.Cir.1988). The

doctrine of prosecution disclaimer precludes patentees from recapturing specific meanings that were previously disclaimed during prosecution. *Omega Eng'g, Inc. v. Raytek Corp.*, 334 F.3d 1314, 1323 (Fed.Cir.2003). Disclaimers of claim scope must be clear and unambiguous. *Middleton, Inc. v. 3M Co.*, 311 F.3d 1384, 1388 (Fed.Cir.2002).

Although "less significant than the intrinsic record in determining the legally operative meaning of claim language," the court may rely on extrinsic evidence to "shed useful light on the relevant art." *Phillips*, 415 F.3d at 1317 (quotation omitted). Technical dictionaries and treatises may help the court understand the underlying technology and the manner in which one skilled in the art might use claim terms, but such sources may also provide overly broad definitions or may not be indicative of how terms are used in the patent. *Id.* at 1318. Similarly, expert testimony may aid the court in determining the particular meaning of a term in the pertinent field, but "conclusory, unsupported assertions by experts as to the definition of a claim term are not useful." *Id.* Generally, extrinsic evidence is "less reliable than the patent and its prosecution history in determining how to read claim terms." *Id.* Extrinsic evidence may be useful when considered in the context of the intrinsic evidence, *id.* at 1319, but it cannot "alter a claim construction dictated by a proper analysis of the intrinsic evidence." *On-Line Techs., Inc. v. Bodenseewerk Perkin-Elmer GmbH*, 386 F.3d 1133, 1139 (Fed. Cir. 2004).

3. Discussion

A. Disputed Terms

The parties dispute the construction of 20 terms. The following table summarizes the parties' proposed constructions of the disputed terms.

Term/Phrase	**Cisco's Proposed Construction**	**Innovative Wireless's Proposed Construction**
1. "CSMA/CD" '895: (Claims 1, 6, 7, 15, 16, 27-37, 40, 48, 51-53) '264: (Claims 5, 8) '473: (Claims 1, 10, 11, 17, 18, 25, 26, 30, 32, 33, 35, 39-42)	[no construction necessary]	"Techniques compatible with connecting to networks such as Ethernet networks, where a device that wishes to transmit on the network listens and checks to see if the channel is free for sending data. If the channel is not free, or if a collision is detected during transmission, the device waits for a small amount of time and tries again."
2. "CSMA/CD interface" '895: (Claims 1, 6, 7, 15, 16, 27-37, 40, 48, 51-53) '264: (Claims 5, 8) '473: (Claims 1, 10, 25, 26, 30, 35, 39-42)	"an interface to a CSMA/CD path or terminal device "	[Plain and ordinary meaning] For the purposes of jury comprehension, Innovative Wireless proposes the following construction: "CSMA/CD": See above

3. "bidirectional communications path"; "communications path" '895: (Claims 1, 3-12, 15, 17-20, 27-37, 40, 48, 49, 51-53) '264: (Claims 5-9) '473: (Claims 1, 3, 4, 7-9, 11, 15, 17-19, 22-24, 26, 30-35, 37, 38, 40-42)	"a wired communications path for exchanging information between two endpoints"	[Plain and ordinary meaning] If the court believes a construction of "bidirectional" is necessary for the purposes of jury comprehension, then Innovative Wireless proposes: "bidirectional" / "bidirectionally": Capable of transmission in either or both directions.
4. "information frame" '895: (Claims 3, 4) '473: (Claims 2, 12, 13, 36)	[no construction necessary]	A group of bits transmitted over a network as a unit which includes a data field.
5. "enveloping information packets in information frames"; "enveloping information corresponding to at least one of the [...] information packets in at least one [...] information frame" '895: (Claim 3) '473: (Claims 2, 12, 36)	"encapsulating intact Ethernet frames containing information packets in information frames" "encapsulating an intact Ethernet frame containing at least one information packet in one information frame"	[Plain and ordinary meaning] For the purposes of jury comprehension, Innovative Wireless proposes the following constructions: "information packets": A unit of data for transmission over networks of some finite size and which may be transmitted over a network by being enveloped in one or more frames. "information frames": See above.
6. "control information" '895: (Claims 1, 4, 5, 48) '264: (Claims 5, 8) '473: (Claims 1, 11, 14, 16, 26, 30, 31, 35)	"information provided in a data or control frame by the [master modem/first end/first modem/control unit/control unit of the first unit/another apparatus] that dictates when information can be communicated over the communications path"	[Plain and ordinary meaning]

7. "supplying information packets [...] to the communications path in dependence upon the control information" '895: (Claim 1)	"providing information packets to the communications path under control of and in response to received control information"	[Plain and ordinary meaning] For the purposes of jury comprehension, Innovative Wireless proposes the following construction: "information packets": See above.
8. "wherein the control information and the dependence on the control information [. . .] are arranged to avoid collisions [. . .] between information packets communicated from the first buffer to the second buffer and information packets communicated from the third buffer to the fourth buffer" '895: (Claim 1)	"wherein information packets from the third buffer are supplied to the communications path only in response to control information so that a communication from the third buffer to the fourth buffer cannot occur when a communication from the first buffer to the second buffer is present on the communications path"	[Plain and ordinary meaning] For the purposes of jury comprehension, Innovative Wireless proposes the following constructions: "collision": The condition where transmissions on a channel overlap, preventing successful transmission. "buffer": A device or storage area used to temporarily store data sent or received over a network. "information packets": See above
9. "control unit" '895: (Claim 48) '264: (Claims 5, 8) '473: (Claim 30)	"a unit that performs the necessary conversion between the Ethernet frames and the ECAP data frames, and generates and responds to the ECAP control and response frames"	[Plain and ordinary meaning]
10. "control unit is responsive to control information, from another apparatus coupled to the communications path" '264: (Claim 8)	"the control unit permits the supply of information to the communications path only in response to control information received by the control unit"	[Plain and ordinary meaning]

11. "half duplex communications"; "half duplex manner" '895: (Claim 48) '264: (Claims 5, 8) '473: (Claims 1, 2, 11, 26, 30, 35, 36)	"form of communication in which communication signals are provided to the communications path so that information is traveling on the communications path in only one direction at any given moment in time"	[Plain and ordinary meaning] For the purposes of jury comprehension, Innovative Wireless proposes the following constructions: "half duplex": Transmission in either direction on a channel, but only in one direction at a time.
12. "using half duplex communications controlled by the first modem" '473: (Claims 1, 35)	"where the information is travelling on the path in only one direction at a time and under control of the first modem"	[Plain and ordinary meaning] For the purposes of jury comprehension, Innovative Wireless proposes the following constructions: "half duplex": See above.
13. "master modem"; "slave modem" '473: (Claim 26)	"a modem at a first end of the bidirectional communications path that controls how all communications are supplied to the path" "a modem at a second end of the bidirectional communications path that supplies information to the path only in response to control information received from the master modem"	[Plain and ordinary meaning] For the purposes of jury comprehension, Innovative Wireless proposes the following constructions: "master modem": A modem having control over other modem(s). "slave modem": A modem which is controlled by a master modem.

14. "multiplexing the modem" '895: (Claims 12, 20)	[Indefinite]	[Plain and ordinary meaning] For the purposes of jury comprehension, Innovative Wireless proposes the following constructions: "multiplexing" / "multiplexed": Techniques for transmitting two or more signals over a channel, such as interleaving transmissions or subdividing a common channel.
15. "multiplexing signals of the first modem" '473: (Claims 5, 20)	[Indefinite] To the extent that this phrase is capable of construction, it should be construed as "combining [signals of the first modem] for transmission as a single signal"	[Plain and ordinary meaning] For the purposes of jury comprehension, Innovative Wireless proposes the following constructions: "multiplexing" / "multiplexed": See above.
16. "multiplexer . . . for multiplexed connections via respective buffers to respective communication paths" '895: (Claim 51)	"device for combining the information packets received by the first unit from multiple communication paths, each path associated with a connection and buffer in the first unit"	[Plain and ordinary meaning] For the purposes of jury comprehension, Innovative Wireless proposes the following constructions: "multiplexing" / "multiplexed": See above. "buffers": See above.

17. "MAC-layer packet grouping of data that is grouped to fit into one MAC-layer packet of CSMA/CD networks" '473: (Claims 1, 11, 26, 30, 35)	[Indefinite]	[Plain and ordinary meaning] For the purposes of jury comprehension, Innovative Wireless proposes the following constructions: "MAC-layer" / "MAC layer": The layer of a network which provides functions between the physical layer and the logical link control layer, including controlling access to the communication channel(s). "packet": A unit of data for transmission over networks of some finite size and which may be transmitted over a network by being enveloped in one or more frames. "CSMA/CD": See above.
18. "MAC layer grouping of information on the CSMA/CD path" '473: (Claim 41)	"an Ethernet frame at the MAC layer"	[Plain and ordinary meaning] For the purposes of jury comprehension, Innovative Wireless proposes the following constructions: "CSMA/CD": See above. "MAC-layer" / "MAC layer": See above.

19. "the half duplex communications are MAC-layer half-duplex such that once information corresponding to a first MAC-layer packet grouping of data has begun to be transmitted into the bidirectional communications path the information corresponding to the first MAC-layer packet grouping of data is completely transmitted into the bidirectional communications path before information corresponding to a second MAC-layer packet grouping of data is allowed to begin to be transmitted into the bidirectional communications path" '473: (Claim 35)	"once a frame has begun to be transmitted on the communications path, the transmission must be received at the other end of the path before a second frame can be transmitted in the opposite direction on the communications path"	[Plain and ordinary meaning] For the purposes of jury comprehension, Innovative Wireless proposes the following constructions: "half duplex": See above. "MAC-layer" / "MAC layer": See above. "packet": See above. "bidirectional" / "bidirectionally": See above.
20. "changing direction of communication of MAC layer groupings of information … after the completion of transmission of the information corresponding to the first information packet" '473: (Claim 40)	"changing direction of flow of frames on the communications path only after a transmitted frame has been received at the other end of the communications path"	[Plain and ordinary meaning] For the purposes of jury comprehension, Innovative Wireless proposes the following constructions: "MAC-layer" / "MAC layer": See above. "information packet": See above.

1. "CSMA/CD"

The initialism "CSMA/CD" stands for "Carrier Sense Multiple Access with Collision Detection." The parties disagree that the term CSMA/CD needs to be construed. Cisco contends that CSMA/CD is a well-known protocol defined by the IEEE 802.3 Working Group[3] and that the patents-in-suit defer to the published IEEE standard. Thus, Cisco argues, a skilled artisan at the time of the patent would understand the use of the term CSMA/CD. Further, Cisco argues that Innovative Wireless's proposed construction is neither helpful nor accurate.

Innovative Wireless contends that CSMA/CD is a term the jury cannot readily understand and that Innovative Wireless's proposed construction is supported by the specification and the IEEE 802.3 standard. Innovative Wireless directs the court to the sentence in the specification that states: "The term CSMA/CD is used herein to refer generically to this technology." '895 Patent, 1:38-40. Innovative Wireless argues that this sentence indicates that CSMA/CD is used throughout the patents-in-suit to describe any network technology that employs a contention scheme similar to the 802.3 scheme. Innovative Wireless further argues that the contention scheme contained in its proposed construction is consistent with the contention scheme overview in the 802.3 standard.

Moreover, Innovative Wireless contends that the "MA" in CSMA/CD shows that CSMA/CD is a technology that relates to connecting to a network. Innovative Wireless argues that "multiple access" shows that the technology relates to connecting to networks in addition to facilitating communications.

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[3] The Institute of Electrical and Electronics Engineers ("IEEE") is a professional association dedicated to advancing technological innovation. The IEEE 802.3 Working Group is the subgroup of IEEE that develops and publishes standards for Ethernet networks. IEEE, *IEEE at a Glance* (August 11, 2014), http://www.ieee.org/about/today/at_a_glance.html.

In light of the clear language contained in the patents' specification, the court concludes that the patentee acted as his own lexicographer and specifically defined the term's use in the context of the patents. The specification defines CSMA/CD:

> Different technologies can be used to facilitate communications on any LAN[4] and throughout the Network, the most common being . . . (CSMA/CD) technology. This is documented in IEEE Standard 802.3 . . . . The 802.3 Standard is based on the 1985 Version 2 Standard for Ethernet and, although there are some differences . . . the two Standards are largely interchangeable and can be considered equivalent as far as this invention is concerned. The term "CSMA/CD" is used herein to refer generically to this technology. Using CSMA/CD, packets of data are communicated in frames that are generally referred to as Ethernet frames. This term is also used herein, regardless of whether the frames comply with the 802.3 Standard or the Ethernet Standard . . . .

'895 Patent, 1:25-45 (footnote added). CSMA/CD is a technology, documented in the IEEE 802.3 standard, used to facilitate network communications. The 802.3 standard is based on the 1985 Version 2 Standard for Ethernet ("Ethernet 2 Standard"). As far as this invention is concerned, the two standards are equivalent. In the patents-in-suit, CSMA/CD is used to generically refer to the technology as defined in either standard. Moreover, the specification references the documented IEEE standard when describing a network technology that uses CSMA/CD. The specification further references the IEEE standard when describing the contention scheme employed in CSMA/CD.

Cisco's argument that the term should be given its ordinary and customary meaning fails. There is a heavy presumption that the term carries its ordinary and customary meaning; however, this presumption is overcome when the patentee acted as his own lexicographer and clearly set forth a

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[4] The initialism "LAN" stands for Local Area Network.

definition of the disputed claim term. *CCS Fitness, Inc. v. Brunswick Corp.*, 288 F.3d 1359, 1366 (Fed. Cir. 2002).

Innovative Wireless's position also misses the mark. Innovative Wireless relies on the use of "generically" in the specification to argue for a particularly broad interpretation. However, within the context of the paragraph, the word generically refers to CSMA/CD as defined in either the 802.3 Standard or the Ethernet 2 Standard. As the patents-in-suit explain, the two standards are interchangeable and equivalent as far as *this invention* is concerned.

The court construes the term CSMA/CD to mean "**CSMA/CD (Carrier Sense Multiple Access with Collision Detection) as defined in either the IEEE 802.3 Standard or the 1985 Version 2 Standard for Ethernet.**"[5]

2. "CSMA/CD interface"

The parties disagree whether this term needs construction. Innovative Wireless argues that the court's construction of CSMA/CD combined with the plain and ordinary meaning of "interface" is the proper construction. Cisco argues that the specification provides specific lexicographical guidance to the meaning of this term as it is used throughout the patents-in-suit. Innovative Wireless argues that Cisco's proffered construction is not directly supported by the specification, and what support there is describes preferred or alternative embodiments.

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[5] These standards may be incomprehensible to a jury. This construction captures the court's sense of the appropriate meaning of CSMA/CD, but the court may very well refine this construction before trial.

Cisco's construction is based on the following passage from the specification:

> The invention further provides a modem for communicating information packets of Ethernet frames . . . comprising: a control unit; an *interface* for supplying and receiving information packets of Ethernet frames . . . . The interface can comprise a *CSMA/CD interface* to a CSMA/CD path, or it can comprise a *direct interface* to a terminal device.

'895 Patent, 6:6-25 (emphasis added).

The court concludes that Cisco's construction improperly limits the term due to Cisco's reliance on a specification passage describing an alternate embodiment of the invention. The specification uses the term "CSMA/CD interface" over 20 times. However, the term is used generally, with no specific indication that the patentee intended a definition different than the plain and ordinary meaning of interface combined with the patentee's clear definition of CSMA/CD.[6] "Interface," on its own, is a regularly understood term, and is used in a wide variety of contexts within the patent. There is no evidence within the claims or the specification that the "interface" in CSMA/CD interface differs from the usage of "interface" elsewhere in the patents-in-suit.

The court concludes, consistent with the term's usage throughout the patents-in-suit, and consistent with the presumption that claim terms are to be given their plain and ordinary meaning, "CSMA/CD interface" is to be given its **plain and ordinary meaning**.

3. "bidirectional communications path" / "communications path"

The dispute over this term may be summed up succinctly: do the Terry patents, read in their entirety, limit the disclosed (bidirectional) communications path to solely wired embodiments?

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6 *See* discussion *supra,* pp. 13-15.

Cisco argues that the specification clearly demonstrates that this invention's sole purpose is providing network access over long-distance two-wire lines. Cisco notes that the patents-in-suit are titled "Information Network Access Apparatus and Methods for Communicating Information Packets Via Telephone Lines," and that the patents-in-suit state at the very beginning that "[t]his invention . . . is particularly concerned with . . . communicating information packets, . . . via two-wire lines such as telephone subscriber lines." '895 Patent, 1:6-10. Moreover, Cisco argues that the patents-in-suit disclaim any network access paths, including a wire path, that are short enough to support conventional, previously known network protocols. Cisco also contends that a wired communication path is the defining characteristic of all variations of the disclosed embodiments. Cisco further argues that the specification's failure to refer to other then-known types of mediums in conjunction with the invention is evidence of purposeful intent to limit the invention's scope to a wired communication path. Cisco argues that wireless communication paths were well-known at the time, but the patents-in-suit never mention a wireless path.

Innovative Wireless contends that the term should be given its broadest ordinary meaning consistent with the written description. Innovative Wireless notes that independent Claims 42, 56, and 71 of the '895 patent recite specific wired communications paths and that independent Claims 1 and 3 of the '264 patent recite a communications path that comprises a two-wire telephone subscriber line. Innovative Wireless further notes dependent Claims 13, 21, 23, and 25 of the '895 patent and dependent Claims 6, 21, 27, and 28 of the '473 recite a two-wire limitation. Innovative Wireless argues that the claim language itself explicitly contemplates a communications path that is broader than a two-wire line. Innovative Wireless objects that Cisco's construction improperly imports a limitation from the preferred embodiment into the claims. Innovative Wireless contends

that the invention's general purpose is to connect devices to CSMA/CD networks over a medium for which CSMA/CD technology is not suitable. According to Innovative Wireless, addressing the distance problem is merely *an* object of the invention along with low cost and high data rates, rather than the *primary* object of the invention

A court may depart from the plain and ordinary meaning of a claim term in only two instances: lexicography and disavowal. *Hill-Rom Servs., Inc. v. Stryker Corp.*, 755 F.3d 1367, 1371 (Fed. Cir. 2014). Neither side argues that the patentee here acted as his own lexicographer to define the communications-path terms in a way specific to the patents-in-suit. Therefore, to conclude that the term requires construction beyond its plain and ordinary meaning, the court would need to find "that the specification [or prosecution history] make[] clear that the invention does not include a particular feature, or is clearly limited to a particular form of the invention." *Id.* (internal citations and quotations omitted). "[A]bsent some language in the specification or prosecution history suggesting that the [limiting feature] is important, essential, necessary, or the 'present invention,' there is no basis to narrow the plain and ordinary meaning of the term . . . . There are no magic words that must be used, but to deviate from the plain and ordinary meaning of a claim term to one of skill in the art, the patentee must, with some language, indicate a clear intent to do so in the patent." *Id.* at 1373.

After thorough consideration of the entire specification, the court finds that the Terry Patents are solely focused on communicating information packets long distances over wired communication paths. The repeated reference to two-wire lines and telephone lines emphasizes that the inventor was focused on this transmission medium as the core of the new technology. The specification identifies the protocol that lies at the heart of the invention and forms the basis of the patented technology:

> Communications between the master modem 34 and the slave modem 32 are carried out in accordance with a new point-to-point protocol which uses collision avoidance to communicate Ethernet frames between the modems. This protocol is described below and for convenience is referred to herein as ECAP . . . . The protocol and modems simply serve to replace a direct (short-distance) connection between the interface 30 and the twisted pair wiring 36 by a remote connection via the (much greater distance) two-wire line. *Thus although as described here the line 12 is a telephone subscriber line, it can be appreciated that the same arrangement of master and slave modems operating in accordance with the new protocol can be used to communicate Ethernet frames via any twisted pair wiring which is too long to permit conventional 10BASE-T or similar LAN interconnections* . . . . It can be seen from the above description that embodiments of the invention are centered on the arrangement and functioning of the modems 32 and 34.

'895 Patent 9:32-10:8 (emphasis added). Where the specification clearly limits the invention to a particular form, and it is clear no broader scope was contemplated, it is proper to construe the claims consistently with that limitation. *In re Rembrandt Technologies, LP*, 496 F. App'x 36, 45 (Fed. Cir. 2012); *Kinik Co. v. Int'l Trade Comm'n.*, 362 F.3d 1359, 1365-66 (Fed. Cir. 2004). By detailing several specific alternate embodiments, the Terry patents clearly contemplate several types of communication paths. However, the preceding passage, read in light of the patent as a whole, makes it clear that the patents' scope is limited to a communication path between modems consisting of twisted-pair wiring that is too long to permit conventional LAN interconnections. This limitation is consistent with the entire written description of the patent and all disclosed embodiments. To conclude otherwise would allow the patent to expand impermissibly beyond what the inventor invented and sought to claim before the Patent Office.

Contrary to Innovative Wireless's argument, this case is distinguishable from *Hill-Rom.* In *Hill-Rom*, the term "datalink" was only described as wired in depictions of preferred embodiments

and never when describing the datalink generally. *Hill-Rom*, 755 F.3d at 1374. In the Terry patents, the communications path is described as a two-wire line and a two-wire telephone subscriber line in descriptions of preferred embodiments. The patentee specifically noted that those examples were alternate embodiments. However, the specification makes plain that embodiments–which this court understands to mean all embodiments–could be enabled which utilized any twisted-pair wiring too long for conventional LAN interconnections. The court finds that no additional construction is required for the word bidirectional, and that a person having ordinary skill in the art would comprehend its meaning.

Therefore, the court construes the terms "bidirectional communications path" to mean "**bidirectional communications path utilizing twisted-pair wiring that is too long to permit conventional 10BASE-T or similar LAN (Local Area Network) interconnections**" and "communications path" to mean "**communications path utilizing twisted-pair wiring that is too long to permit conventional 10BASE-T or similar LAN interconnections.**"

4. "information frame"

Although Cisco believes that no construction of this term is necessary, both parties agree, at least in the alternative, that an information frame is a group of bits which are transmitted over a network as a unit. Thus, the crux of the dispute over this term is whether an information frame must include a data field. Cisco contends that Innovative Wireless's construction including a "data field" is ambiguous as to the scope of data. According to Cisco, it is unclear whether data includes control and error-checking information. Cisco argues that when an information frame is required by the claims to have a particular structure, the claims themselves describe that structure. Cisco further

argues that the specification does not support the data field limitation. Finally, Cisco notes that the specification repeatedly refers generically to both data payloads and control bits as "information."

Innovative Wireless argues that the specification teaches that an information frame is a particular type of frame, one that carries information; Innovative Wireless contends that these are distinct from control frames, which Innovative Wireless argues contain no data. Innovative Wireless argues that the patentee uses information frame and data frame interchangeably. Innovative Wireless contends that if the patentee intended information frame to mean any kind of frame, the patentee just would have called it a frame.

The patents' specification only references information frames in one paragraph, providing little additional guidance as to the term's definition. An information frame is introduced as something that envelopes an information packet and has an error check field. '895 Patent, 3:58-59. The information frame may or may not contain control information from the master modem or response information from the slave modem. '895 Patent, 3:62-65. If the control and response information is not included in the information frame, it may be sent in further frames. '895 Patent, 3:62-65. The distinction between the information frames and other frames is the encapsulation of information packets. Consistently throughout the patents-in-suit, and in every claim that describes information frames, information frames envelop information packets. Additionally, within the context of the Terry patents, every information packet is received from or destined to the CSMA/CD path.

The court construes the term "information frame" to mean "**a group of bits transmitted as a unit over a network that contains an information packet and is received from or destined to the CSMA/CD path.**"

5. "enveloping information packets in information frames" / "enveloping information corresponding to at least one of the [...] information packets in at least one [...] information frame"

The parties' dispute over this term centers on whether enveloped information packets must be intact Ethernet frames. Cisco argues that communicating Ethernet frames is the stated goal of the invention. Ciscto further argues that the specification consistently uses "enveloping" to describe encapsulating an intact Ethernet frame into an ECAP (Ethernet Collision Avoidance Protocol) frame. By using the term envelop, Cisco argues, the patentee intended to capture the specific embodiment illustrated in Figure 9.

Innovative Wireless contends that Cisco's construction rewrites the claims to import additional limitations without a textual basis from the intrinsic record. Moreover, Innovative Wireless argues that Cisco's use of "intact" in its construction violates the doctrine of intra-claim differentiation. Innovative Wireless contends that since an intact Ethernet frame contains an error check field, Cisco's construction would render the language describing the error check field in the information frame superfluous.

Cisco's proposed construction is unwieldy and is not directly supported by the claim language or specification. More importantly, with the exception of "information packets" and the previously defined "information frame," there are no words in the disputed claim phrases which require construction beyond their plain and ordinary meaning. The phrases contain straightforward, easily understood language that is not technical in nature. The court must not rewrite claim language without a textual hook in the claim language. *NTP, Inc. v. Research in Motion, Ltd.*, 392 F.3d 1336, 1363 (Fed. Cir. 2004). The court concludes that the only part of the disputed claim term that truly requires construction is "information packets."

The patents' specification describes an information packet as distinct from an Ethernet frame. It is unequivocal from the specification, the patents' described embodiments, and the claim language that information packets may contain all or certain parts of Ethernet frames. Also, it is clear that although information packets are "generally referred to as Ethernet frames," they are not identical; otherwise the patentee would have only referred to Ethernet frames instead of the generic information packets.

The court therefore concludes that the phrases "enveloping information packets in information frames" and "enveloping information corresponding to at least one of the [...] information packets in at least one [...] information frame" are to be given their **plain and ordinary meaning**. The court further construes "information packets" to mean "**units of data for transmission over networks that contain all or part of an Ethernet frame**."

6. "control information"

The parties disagree that this term needs to be construed. Cisco contends that control information is central to the claimed invention and that Cisco's construction ensures that the asserted claims' scope remain aligned with the invention. Cisco argues that the patents-in-suit repeatedly teach that the inventions' half-duplex communications use a collision avoidance protocol. As explained in the specification, the protocol defines that the master modem has priority and control over the slave modem. The master modem determines when the slave modem may send information via the bidirectional communications path. The control by the master modem avoids collisions on the communications path. Cisco contends that collision avoidance is not simply a desired goal, but is the absolute result because the master modem-control scheme ensures that collisions cannot occur.

Cisco further argues that the patents-in-suit's prosecution history confirms the importance of the master modem-control scheme. Cisco argues that the patentee took the position that control information was a novel aspect of the rejected claim in order to overcome prior-art rejection. Finally, Cisco contends that Innovative Wireless's argument about the specification's reference to an unexpected frame mischaracterizes the specification. According to Cisco, the specification describes the unexpected-frame scenario as indicative of an error condition where some but not all of the expected response was lost during transmission, not, as Innovative Wireless contends, when the slave modem sends data that the master modem did not permit.

Innovative Wireless contends that Cisco's proposed construction improperly imports limitations from preferred embodiments and that Cisco's construction is unsupported by the intrinsic record. Innovative Wireless further argues that each claim containing the term has its own specific language detailing how control information is defined in that claim. Innovative Wireless contends that it would be improper to override each specific choice of claim language with Cisco's proposed construction. Innovative Wireless also argues that the specification addresses that the master modem may receive unexpected frames, meaning that the patent contemplates that the master modem cannot truly dictate when the slave modem sends data.

The language used in the claim defines the scope of the invention. *Phillips,* 415 F.3d at 1312. Independent Claim 1 and dependent Claims 4 and 5 of the '895 Patent describe a control regime where the master interface to the communications path supplies control information and the slave interface depends on that control information to transmit data. In the '264 Patent, Claim 5 describes a master apparatus that contains a control unit that produces control information to control a slave apparatus to provide half-duplex communications. Claim 8 of the '264 Patent describes the

corresponding slave unit that responds to the control information. Independent Claims 1 and 11 and dependent Claims 14 and 16 of the '473 patent describe a similar control regime where the first modem sends control information to a second modem to enable half-duplex communications. Further, Claims 26 and 35 of the '473 Patent describe a master modem that sends control information to control a slave modem to enable half-duplex communications. In contrast, Claim 48 of the '895 Patent and claims 30 and 31 of the '473 Patent describe another arrangement; in these claims both the first/master and the second/slave ends are comprised, in part, of a control unit.

In sum, the claims as a whole describe a control scheme where the control units on both ends of the communications path exchange control information in order to facilitate half-duplex communications. Moreover, the patents-in-suit's prosecution history acknowledges that the master modem control scheme was a distinguishing feature for the claims dealing with that control scheme. The prosecution history further reflects that the exchange of control information to enable half-duplex communications is the crux of the distinguishing features which allowed patentability over the prior art.

The court construes "control information," read in light of how it is used in the Terry Patents' claims and specification and interpreted in light of the patents' prosecution history, to mean "**information exchanged on the communications path to enable half-duplex communications**."

7. "supplying information packets … to the communications path in dependence upon the control information"

8. "wherein the control information and the dependence on the control information [. . .] are arranged to avoid collisions [. . .] between information packets communicated from the first buffer to the second buffer and information packets communicated from the third buffer to the fourth buffer"

Cisco seeks to rewrite these two claim phrases with language it argues will facilitate an understanding of the "scope of the claims in the context of the" Terry Patents. Cisco argues that its construction is consistent with the patents' "requiring that information is provided to the path 'under control of and in response to received control information.'" Innovative Wireless counters that the claim phrase has an easily understood plain and ordinary meaning and any necessary clarification to the phrase can be accomplished by defining individual words or phrases that might be confusing to a jury.

The court concludes that these two disputed phrases are composed of words that have plain and ordinary meanings and, when read in the light of the specification and the court's other constructions, a person of ordinary skill in the art would easily comprehend each phrase's meaning without further elaboration. The court will not engage in rewriting lengthy claim phrases without specific textual guidance in the specification or intrinsic record.

Accordingly, the court concludes that "supplying information packets … to the communications path in dependence upon the control information" and "wherein the control information and the dependence on the control information [. . .] are arranged to avoid collisions [. . .] between information packets communicated from the first buffer to the second buffer and information packets

communicated from the third buffer to the fourth buffer" are to be given their **plain and ordinary meaning** with no additional construction required.

9. "control unit"

10. "control unit is responsive to control information, from another apparatus coupled to the communications path"

Cisco concedes in its opening brief that "at first blush, one might interpret the phrase [control information] to mean simply a unit that controls." Due to the presumption that a claim term carries its plain and ordinary meaning, in order for the court to adopt an alternative construction, Cisco must show that the patentee acted as his own lexicographer or included in the specification expressions of manifest exclusion or restriction, representing a clear disavowal of claim scope. *Thorner v. Sony Computer Entertainment America, LLC*, 669 F.3d 1362, 1365 (Fed. Cir. 2012) (citations omitted). Innovative Wireless argues that Cisco has made no such showing and that Cisco's reliance on language describing preferred embodiments improperly limits the claim language.

The court finds that nowhere in that body of the patent does the patentee define control unit in a way different from the plain and ordinary meaning of the term as would have been understood by a person having ordinary skill in the art of the invention. Neither does the patentee disavow claim scope or indicate exclusions or restrictions on the term. The usage of "control unit" in the claims is clear, and there is no indication that further definition is required by the context of the claims or specification. Furthermore, with regard to the phrase "control unit is responsive . . .," the court finds that the remaining words in the phrase are clear and readily understood. There is no indication in the

intrinsic record that the court need adopt Cisco's rewriting of the disputed claim phrase, as each of the remaining words–alone and in conjunction–have an easily understood meaning.

Accordingly, the court concludes that "control unit" and "control unit is responsive to control information, from another apparatus coupled to the communications path" are to be given their **plain and ordinary meaning**.

11. "half duplex communications"; "half duplex manner"

12. "using half duplex communications controlled by the first modem"

The parties present opposed arguments regarding the inventions' half-duplex communications terms. The court finds each side's arguments misplaced in light of the clear definition introduced early in the patents' specification:

> The *half duplex communications*, which can alternatively be considered as time division duplex or time compression multiplex communications, *avoid collisions or interference between information packets communicated in the two directions of communication on the communications path by ensuring that the communications in the two directions take place at different times*.

'895 Patent, 3:47-53 (emphasis added). The court concludes that this unequivocal statement defining the inventions' half-duplex communications indicates how the patentee intended for the term to be understood in the context of the patents' claims.

Therefore, the court construes "half duplex communications" and "half duplex manner" to mean "**communications which avoid collisions or interference between information packets communicated in the two directions of communication on the communications path by ensuring that the communications in the two directions take place at different times**." The court further

concludes that the term phrase "using half duplex communications controlled by the first modem" should be given its **plain and ordinary meaning** in light of the court's construction of "half duplex communications."

13. "master modem"; "slave modem"

The nature of the relationship between the master and slave modems is the focus of the parties' dispute over this term, which appears in the '473 Patent's independent Claim 26. Cisco argues that the master modem must have "complete control," and that the slave modem supplies information to the communications path "only in response to" information received from the master modem. The court finds, however, that Cisco attempts to import limitations that are not present in the claim language and not supported by the patent's specification. Innovative Wireless correctly argues that the relationship between the master and slave modems is described in the claim itself: "the master modem controls the slave modem by control information . . . so that communications of at least the information corresponding to the Ethernet frames on the bidirectional communications path take place in a half-duplex manner. . . ." '473 Patent, Claim 26. Further, the specification is consistent with the term's usage in the claim language and does not support Cisco's insertion of additional limitations on the terms. The court agrees with Innovative Wireless that the use of these terms in the patent is also "consistent with the well understood meaning in the computer and networking fields that 'master' and 'slave' refers to a general concept of control. . . ." The court finds that a person of ordinary skill in the art would readily understand the terms as used in the claim and further informed by the specification.

Accordingly, the court concludes that "master modem" and "slave modem" are to be given their **plain and ordinary meaning** with no further construction required.

14. "multiplexing the modem"

15. "multiplexing signals of the first modem"

Cisco argues that these two terms are indefinite. *See* 35 U.S.C. § 112. Although the parties initially briefed and argued at the claim-construction hearing using the Federal Circuit's earlier standard for indefiniteness, both parties submitted additional briefing to update their argument to incorporate the new standard reflected in the Supreme Court's recent *Nautilus* decision. A patent is invalid for indefiniteness "if its claims, read in light of the specification delineating the patent, and the prosecution history, fail to inform, with reasonable certainty, those skilled in the art about the scope of the invention." *Nautilus, Inc. v. Biosig Instruments, Inc.*, 134 S. Ct. 2120, 2124 (2014).

Cisco contends that the Terry Patents' specification essentially describes multiplexing "as a term of art that is defined consistently with its usage," but that the claims use the term multiplexing "in an ambiguous and possibly opposite way." Cisco argues that it is unclear if the claim language is referring to an act as multiplexing that could be more correctly understood as demultiplexing; therefore, according to Cisco, the claims are indefinite. Innovative Wireless argues that the specification makes it clear that the term multiplexing, as used in the claims, includes both directions of the multiplexing process performed by the master modem, and contends that multiplexing as generally used in the claims combines the "multiplexing" and "demultiplexing" directions.

The patents' specification supports Innovative Wireless's argument: "the master modem 34 can provide multiplexed operations for a plurality of slave modems, so that in practice the

transmitting and receiving processes can take place simultaneously and independently in a multiplexed manner." '895 Patent 14:26-36. The specifications and claims consistently describe the overall multiplexing arrangement of one preferred embodiment with multiple slave modems per master modem. Additionally, the claims containing these terms expressly describe the communications path as bidirectional. Therefore, the modem must multiplex and demultiplex information sent over the communications path; this is consistent with a usage of the term "multiplexing" to describe the overall multiplexing process.

The court concludes that the claim terms, when read in light of the specification, provide substantial guidance for a person skilled in the art to understand the bounds of the term, and therefore the scope of the invention. A person of ordinary skill in the art of the Terry Patents would be able to discern, with reasonable certainty, from the context of the claim and the terms' usage in the specification, what multiplexing means in the context of these disputed claim terms. Therefore, the court finds that these claim terms are not indefinite.

Moreover, as used in the patent, multiplexing is a well-defined and previously known technique that would have a clearly understood meaning to a person of ordinary skill in the art. Nothing in the claim language or specification demonstrates that the patentee intended anything other than the plain and ordinary meaning of the term.

Therefore, the court concludes that "multiplexing the modem" and "multiplexing signals of the first modem" should be given their **plain and ordinary meaning** with no further construction required.

16. "multiplexer . . . for multiplexed connections via respective buffers to respective communication paths"

Cisco argues that its proposed construction provides clarity and is based on the intrinsic record. Innovative Wireless again argues that the disputed phrase contains words that are easily understood combined with words which have either already been defined or individual words that can be defined; Innovative Wireless opposes Cisco's attempt at wholesale rewriting of the claim phrase.

In light of the court's previous constructions and the court's conclusion that the disputed phrase contains easily understood words that have a clear meaning–a meaning that a person having skill in the art would understand without further elaboration–the court concludes that this disputed phrase shall be given its **plain and ordinary meaning** with no further construction required.

17. "MAC-layer packet grouping of data that is grouped to fit into one MAC-layer packet of CSMA/CD networks"

Cisco argues that this term is indefinite under the *Nautilus* standard. Cisco asserts that because the phrase does not appear in its entirety in the specification there is uncertainty about its meaning. Additionally, Cisco argues that the specification does not describe how the "grouping of data" can be "grouped to fit" into a MAC-layer[7] packet. Innovative Wireless argues that the specification "plainly discloses one such way of grouping to fit." Additionally, Innovative Wireless argues that the "longstanding rule that phrases in the claims need not be recited word-for-word in the specification" has not been upset by the *Nautilus* decision. *See Bancorp Servs., LLC v. Harford Life Ins. Co.*, 359 F.3d 1367, 1372 (Fed. Cir. 2004).

[7] The initialism "MAC" stands for Medium Access Control.

The court finds Innovative Wireless's citation to the specification instructive. In describing one embodiment, the patentee disclosed that "refinements can include provisions for sending multiple data frames successively in either direction as described above, concatenating or merging control and/or data frames sent in the same direction." '895 Patent, 17:31-35. Additionally, the specification introduces the term MAC-layer. The court has construed CSMA/CD in this order. In light of the disclosures in the specification, the court concludes that the specification provides adequate guidance for a person skilled in the art to understand the bounds of the claim term. Therefore, the court concludes that the claim is not indefinite under the *Nautilus* standard. *Nautilus*, 134 S. Ct. at 2124.

Further, as each word (or group of words) in the disputed claim phrase has a meaning that would be readily understood on its own or when read in light of the specification, the court concludes that this term shall be given its **plain and ordinary meaning** with no further construction required.

<u>18. "MAC layer grouping of information on the CSMA/CD path"</u>

Cisco argues that this disputed claim phrase, which only appears as a complete phrase in the '473 Patent's Claim 41, contains highly technical language and requires a construction for jury comprehension. Cisco contends that its construction, which rewrites the entire phrase, is supported by the intrinsic record. Cisco urges that the only disclosed "grouping of data" at the MAC-layer is an "Ethernet frame." Further, Cisco directs the court to the '473 Patent's prosecution history to support its arguments that the patentee represented that the specification "describes the format of an Ethernet frame at the MAC layer." (emphasis omitted).

Innovative Wireless responds that the disputed phrase merely constitutes a handful of technical terms connected with everyday English words, which are entitled to their ordinary meaning.

The court agrees. As previously discussed, the use of MAC layer is consistent with its usage in the specification and would be easily understood by a person having ordinary skill in the art. CSMA/CD has already been defined by the court. There is nothing in the intrinsic record that rises to the level of disavowal or lexicography that indicates to the court that the remainder of the phrase carries anything other than its plain and ordinary meaning.

The court concludes that "MAC layer grouping of information on the CSMA/CD path" shall be given its **plain and ordinary meaning** with no further construction required.

19. "the half duplex communications are MAC-layer half-duplex such that once information corresponding to a first MAC-layer packet grouping of data has begun to be transmitted into the bidirectional communications path the information corresponding to the first MAC-layer packet grouping of data is completely transmitted into the bidirectional communications path before information corresponding to a second MAC-layer packet grouping of data is allowed to begin to be transmitted into the bidirectional communications path"

Cisco characterizes the dispute over this lengthy claim phrase as being focused on the meaning of "completely transmitted." Cisco also urges that the dispute is similar to the parties dispute over the "half-duplex" terms.[8] Cisco contends that completely transmitted "means exactly that;" still, Cisco proposes to rewrite the claim phrase in its entirety to clarify that "once a device begins transmission of a frame, a device at the other end of the path cannot begin a transmission until that device received the previously transmitted frame." Innovative Wireless argues that the claim phrase

8 *See* discussion *supra,* pp. 27-28.

should be afforded its plain and ordinary meaning and that the specification does not support the narrow construction Cisco seeks.

The court finds that the claim phrase, read in its entirety, is composed of a combination of technical terms, some of which have been construed by this court, and readily understand English words; a person having ordinary skill in the art would be able to understand the claim phrase readily and comprehend the meaning based on the teaching of the specification and the claim language itself. Despite Cisco's argument that the patent teaches that collisions are "prevented," the court does not find such a clear statement that would warrant adoption of Cisco's narrow construction. The specification anticipates, in at least some embodiments, the possibility of unexpected frames or other devices on the communications path erroneously transmitting frames despite the control scheme implemented by the invention. The court agrees with Cisco that "completely transmitted" means exactly what it says; that meaning requires no further elaboration, nor does the remainder of the claim phrase.

The court concludes that the disputed claim phrase "the half duplex communications are MAC-layer half-duplex . . . into the bidirectional communications path" shall be given its **plain and ordinary meaning** with no further construction required.

<u>20. "changing direction of communication of MAC layer groupings of information ... after the completion of transmission of the information corresponding to the first information packet"</u>

The parties' dispute over this term is focused on the meaning of "after the completion of transmission." Cisco argues only that the control scheme taught by the Terry Patents requires "waiting" by the slave device and operating only in response to a received frame. Cisco seeks a

construction that the flow on the communications path changes only after a transmitted frame is received. Innovative Wireless argues that Cisco's construction should be rejected based upon the language in the claim itself, and that the term should be given its plain and ordinary meaning.

The court looks first to the language of the claim to determine the proper construction of a disputed term; here the language is perfectly clear. Innovative Wireless is correct that the claim language itself says the direction of transmission is changed after the completion of transmission; it does not say the direction is changed after the reception of the groupings of information. The specification sections cited by Cisco do not rise to the level of expression of manifest exclusion or restriction sufficient to justify an adoption of Cisco's rewriting of the claim language. Furthermore, the language used in this disputed claim phrase is normal, everyday English and has a plain meaning that would be evident to a person having ordinary skill in the art.

The court concludes that the disputed term "changing direction of communication . . . corresponding to the first information packet" shall be given its **plain and ordinary meaning** with no further construction required.

B. Summary Table of Adopted Constructions

Claim Term/Phrase	**Court's Construction**
1. "CSMA/CD" '895: (Claims 1, 6, 7, 15, 16, 27-37, 40, 48, 51-53) '264: (Claims 5, 8) '473: (Claims 1, 10, 11, 17, 18, 25, 26, 30, 32, 33, 35, 39-42)	**CSMA/CD (Carrier Sense Multiple Access with Collision Detection) as defined in either the IEEE 802.3 Standard or the 1985 Version 2 Standard for Ethernet**

2. "CSMA/CD interface" '895: (Claims 1, 6, 7, 15, 16, 27-37, 40, 48, 51-53) '264: (Claims 5, 8) '473: (Claims 1, 10, 25, 26, 30, 35, 39-42)	**[plain and ordinary meaning]**
3. "bidirectional communications path"; "communications path" '895: (Claims 1, 3-12, 15, 17-20, 27-37, 40, 48, 49, 51-53) '264: (Claims 5-9) '473: (Claims 1, 3, 4, 7-9, 11, 15, 17-19, 22-24, 26, 30-35, 37, 38, 40-42)	**bidirectional communications path utilizing twisted-pair wiring that is too long to permit conventional 10BASE-T or similar LAN (Local Area Network) interconnections** **communications path utilizing twisted-pair wiring that is too long to permit conventional 10BASE-T or similar LAN interconnections**
4. "information frame" '895: (Claims 3, 4) '473: (Claims 2, 12, 13, 36)	**a group of bits transmitted as a unit over a network that contains an information packet and is received from or destined to the CSMA/CD path**
5. "enveloping information packets in information frames"; "enveloping information corresponding to at least one of the [...] information packets in at least one [...] information frame" '895: (Claim 3) '473: (Claims 2, 12, 36)	**[plain and ordinary meaning]** "information packets": **units of data for transmission over networks that contain all or part of an Ethernet frame**

6. "Control information" '895: (Claims 1, 4, 5, 48) '264: (Claims 5, 8) '473: (Claims 1, 11, 14, 16, 26, 30, 31, 35)	**information exchanged on the communications path to enable half-duplex communications**
7. "supplying information packets [...] to the communications path in dependence upon the control information" '895: (Claim 1)	**[plain and ordinary meaning]**
8. "wherein the control information and the dependence on the control information [. . .] are arranged to avoid collisions [. . .] between information packets communicated from the first buffer to the second buffer and information packets communicated from the third buffer to the fourth buffer" '895: (Claim 1)	**[plain and ordinary meaning]**
9. "control unit" '895: (Claim 48) '264: (Claims 5, 8) '473: (Claim 30)	**[plain and ordinary meaning]**
10. "control unit is responsive to control information, from another apparatus coupled to the communications path" '264: (Claim 8)	**[plain and ordinary meaning]**

11. "half duplex communications"; "half duplex manner" '895: (Claim 48) '264: (Claims 5, 8) '473: (Claims 1, 2, 11, 26, 30, 35, 36)	**"communications which avoid collisions or interference between information packets communicated in the two directions of communication on the communications path by ensuring that the communications in the two directions take place at different times"**
12. "using half duplex communications controlled by the first modem" '473: (Claims 1, 35)	**[plain and ordinary meaning]**
13. "master modem"; "slave modem" '473: (Claim 26)	**[plain and ordinary meaning]**
14. "multiplexing the modem" '895: (Claims 12, 20)	**[not indefinite]** **[plain and ordinary meaning]**
15. "multiplexing signals of the first modem" '473: (Claims 5, 20)	**[not indefinite]** **[plain and ordinary meaning]**
16. "multiplexer . . . for multiplexed connections via respective buffers to respective communication paths" '895: (Claim 51)	**[plain and ordinary meaning]**
17. "MAC-layer packet grouping of data that is grouped to fit into one MAC-layer packet of CSMA/CD networks" '473: (Claims 1, 11, 26, 30, 35)	**[not indefinite]** **[plain and ordinary meaning]**
18. "MAC layer grouping of information on the CSMA/CD path" '473: (Claim 41)	**[plain and ordinary meaning]**

19. "the half duplex communications are MAC-layer half-duplex such that once information corresponding to a first MAC-layer packet grouping of data has begun to be transmitted into the bidirectional communications path the information corresponding to the first MAC-layer packet grouping of data is completely transmitted into the bidirectional communications path before information corresponding to a second MAC-layer packet grouping of data is allowed to begin to be transmitted into the bidirectional communications path" '473: (Claim 35)	**[plain and ordinary meaning]**
20. "changing direction of communication of MAC layer groupings of information … after the completion of transmission of the information corresponding to the first information packet" '473: (Claim 40)	**[plain and ordinary meaning]**

4. Conclusion

For the above reasons, the court construes the disputed claims as noted and so **ORDERS**. No further claim terms require construction.

IT IS FURTHER ORDERED that this case is **SET** for a **Scheduling Conference** on **March 9, 2015, at 2:00 p.m.**, in Courtroom 7, Seventh Floor, United States Courthouse, 501 W. 5th Street, Austin, Texas 78701. The parties shall meet and confer in advance of that date in an attempt to settle this case. If the case is not settled, the parties shall confer in an attempt to reach agreement on a schedule to follow for the remainder of this case. The court will render a Scheduling Order as a result of the **March 9, 2015** conference.

SIGNED this 8th day of January, 2015

LEE YEAKEL
UNITED STATES DISTRICT JUDGE

ADDENDUM C

US005912895A

United States Patent [19]

Terry et al.

[11] **Patent Number: 5,912,895**

[45] **Date of Patent: Jun. 15, 1999**

[54] **INFORMATION NETWORK ACCESS APPARATUS AND METHODS FOR COMMUNICATING INFORMATION PACKETS VIA TELEPHONE LINES**

[75] Inventors: **John Brian Terry**, Cumming; **Roger St. Patrick Richards**, Marietta, both of Ga.

[73] Assignee: **Northern Telecom Limited**, Montreal, Canada

[21] Appl. No.: **08/640,705**

[22] Filed: **May 1, 1996**

[51] **Int. Cl.**[6] **H04L 12/413**

[52] **U.S. Cl.** **370/445**; 375/222

[58] **Field of Search** 370/276, 279, 370/280, 293, 294, 445, 446, 447, 448; 375/222; 395/831, 200.8, 309, 834, 883

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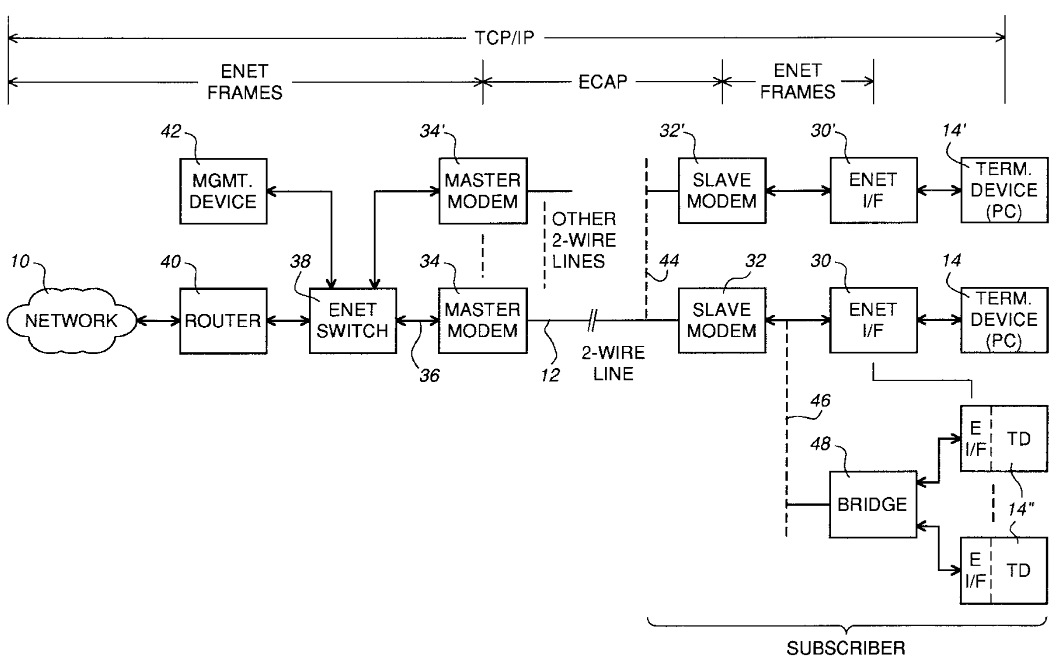
Primary Examiner—Ajit Patel
Attorney, Agent, or Firm—Foley & Lardner

[57] **ABSTRACT**

Access to a CSMA/CD (Carrier Sense Multiple Access with Collision Detection) network is provided via a telephone line by providing a master modem at the head end and a slave modem at the subscriber end of the line. The master modem provides a CSMA/CD interface to the network and controls half duplex communications with the slave modem via the line to avoid collisions of information packets on the line. The information packets are enveloped in frames on the line with error checking information; control information between the modems is contained in the same and/or in separate frames. The modulation method and signal bandwidth can be varied depending on errors to provide optimum communications capacity via any particular line, and a ratio of upstream to downstream information packets can be varied depending on buffer fills at the modems. The master modem can be multiplexed for multiple lines. The modulated signal frequencies are above telephone signal frequencies so that each line can be frequency diplexed for simultaneous telephone communications.

71 Claims, 8 Drawing Sheets



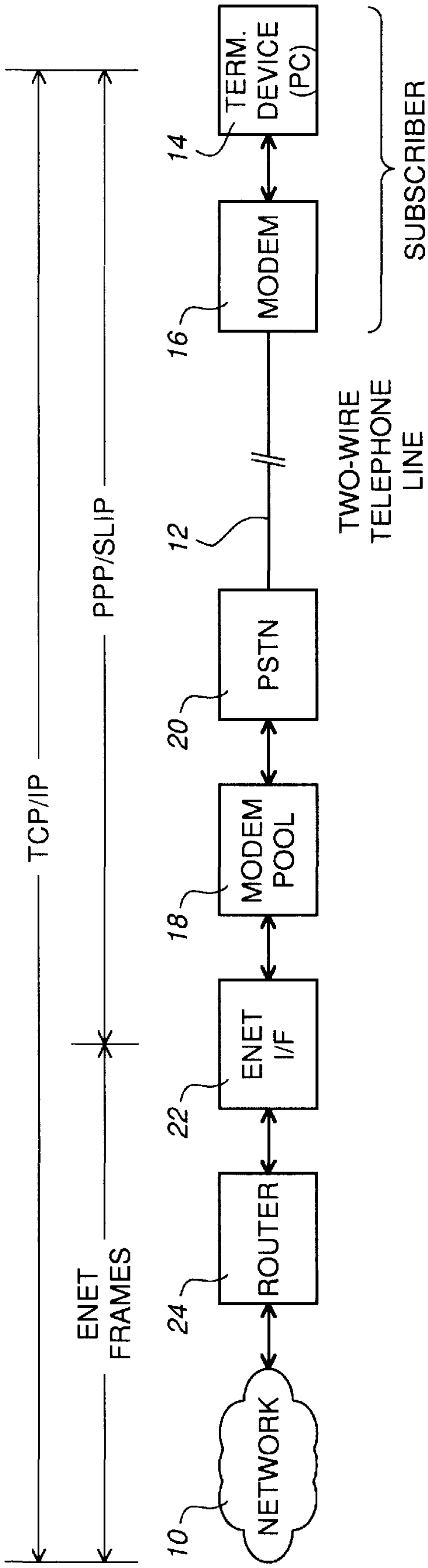


Fig. 1 PRIOR ART

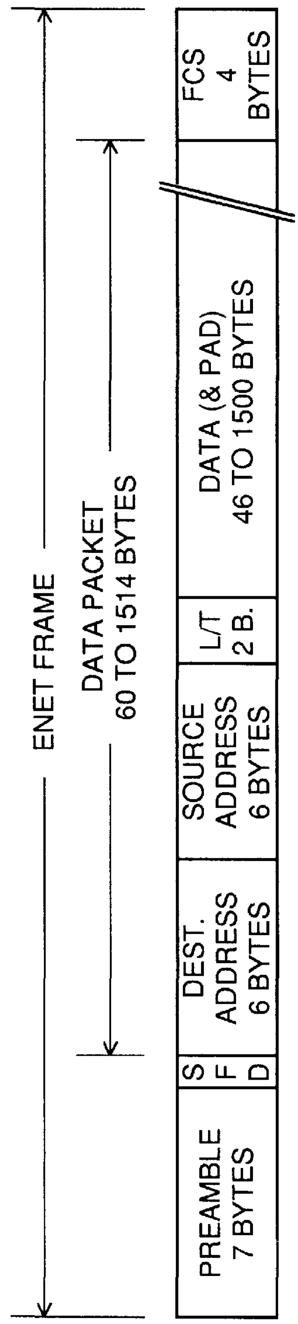


Fig. 2 PRIOR ART

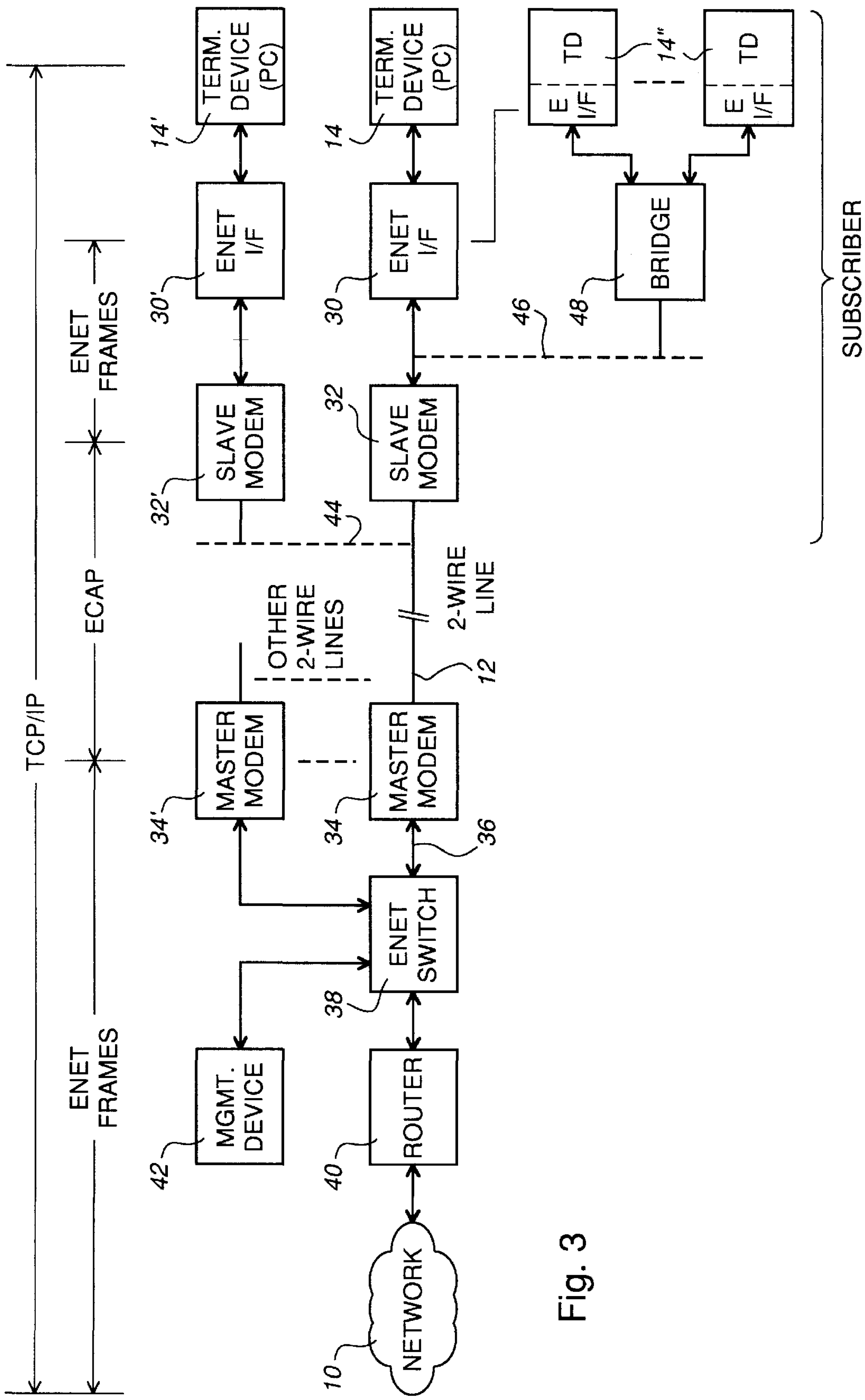

TCP/IP
ENET FRAMES
ECAP
ENET FRAMES
TERM. DEVICE (PC)
14'
TERM. DEVICE (PC)
14
TD
E I/F
14"
TD
E I/F
ENET I/F
30'
ENET I/F
30
BRIDGE
48
46
SLAVE MODEM
32'
SLAVE MODEM
32
44
OTHER 2-WIRE LINES
2-WIRE LINE
12
MASTER MODEM
34'
MASTER MODEM
34
36
ENET SWITCH
38
MGMT. DEVICE
42
ROUTER
40
NETWORK
10
SUBSCRIBER

Fig. 3

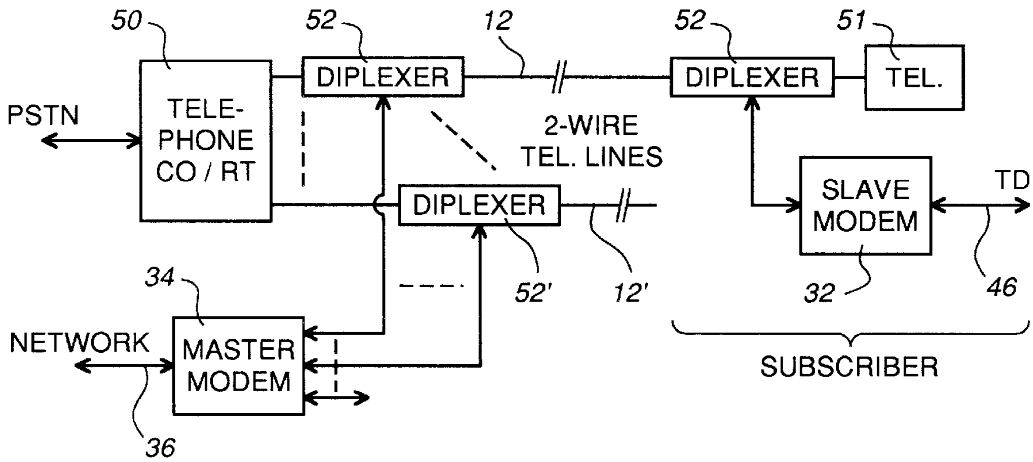


Fig. 4

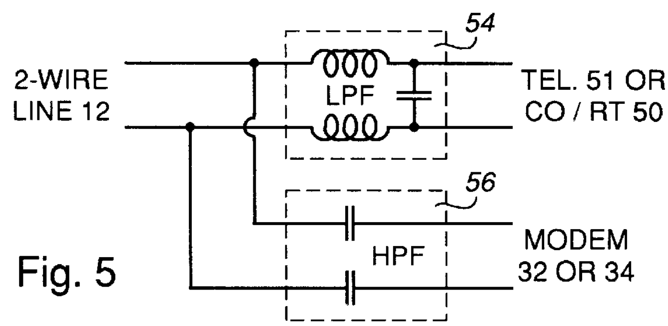


Fig. 5

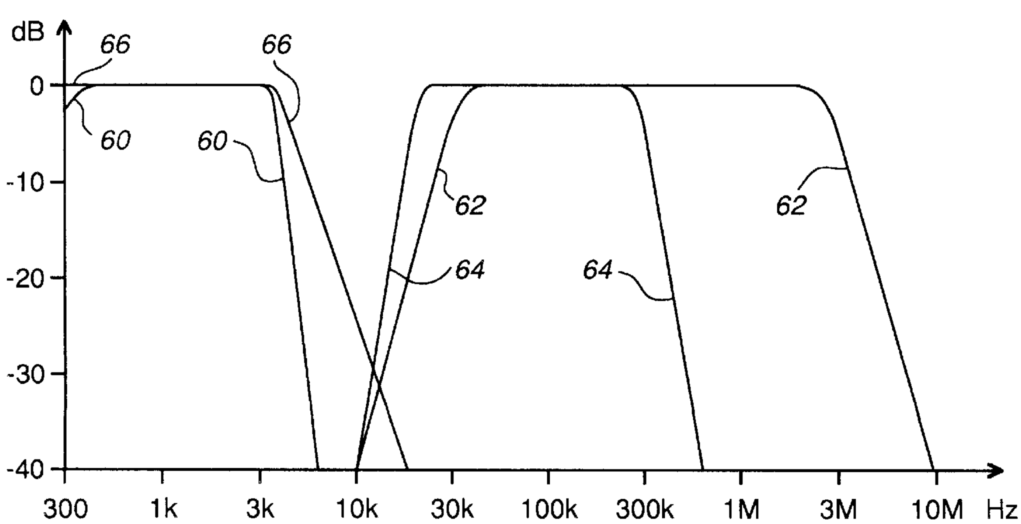


Fig. 6

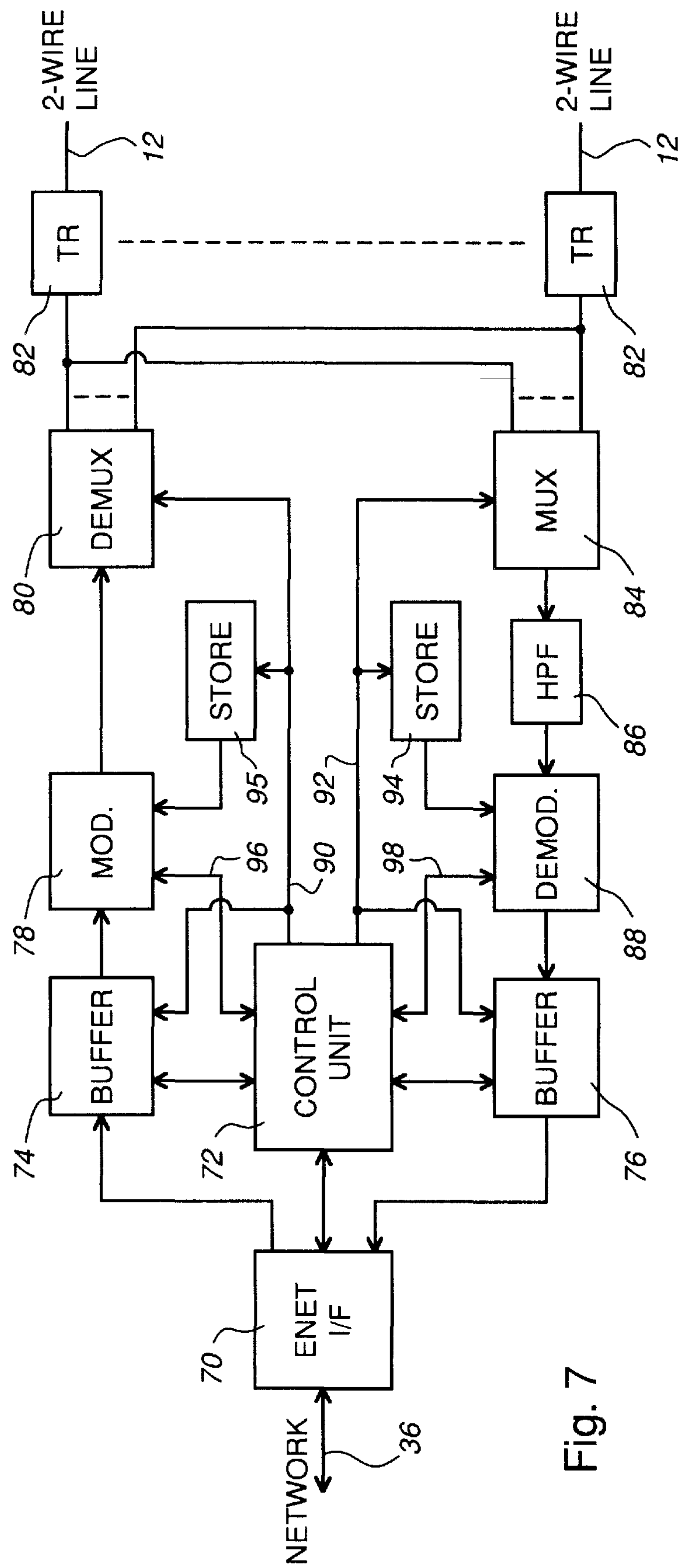

2-WIRE LINE
12
TR
82
2-WIRE LINE
12
TR
82
DEMUX
80
MUX
84
STORE
95
STORE
94
HPF
86
92
MOD.
78
96
90
98
DEMOD.
88
BUFFER
74
CONTROL UNIT
72
BUFFER
76
ENET I/F
70
NETWORK
36

Fig. 7

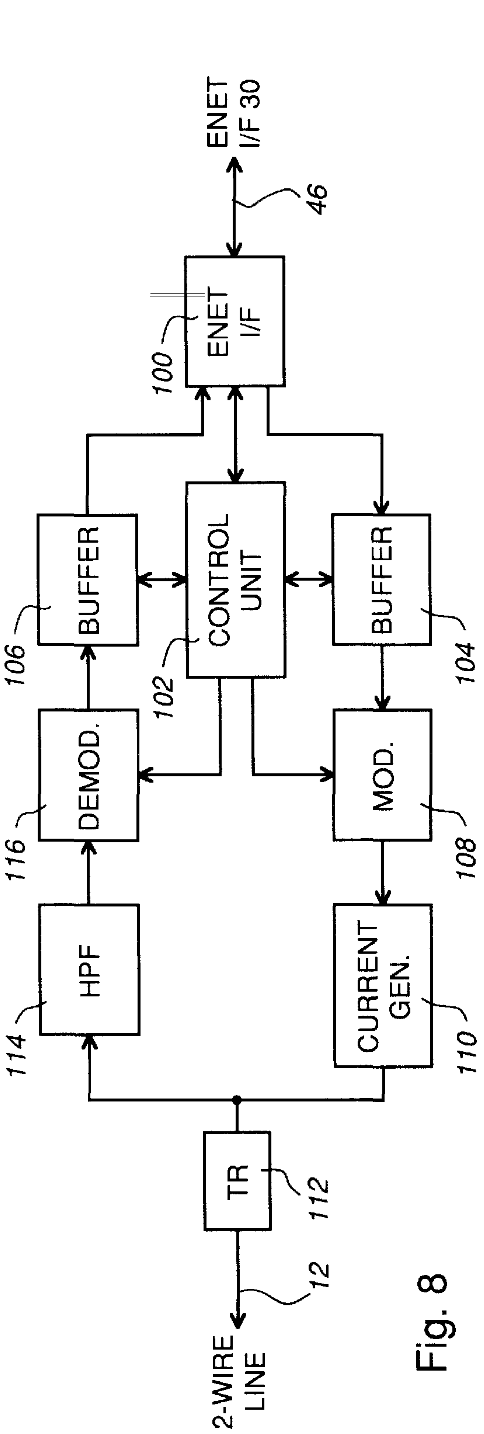

ENET I/F 30
46
ENET I/F
100
BUFFER
106
CONTROL UNIT
102
BUFFER
104
DEMOD.
116
MOD.
108
HPF
114
CURRENT GEN.
110
TR
112
12
2-WIRE LINE

Fig. 8

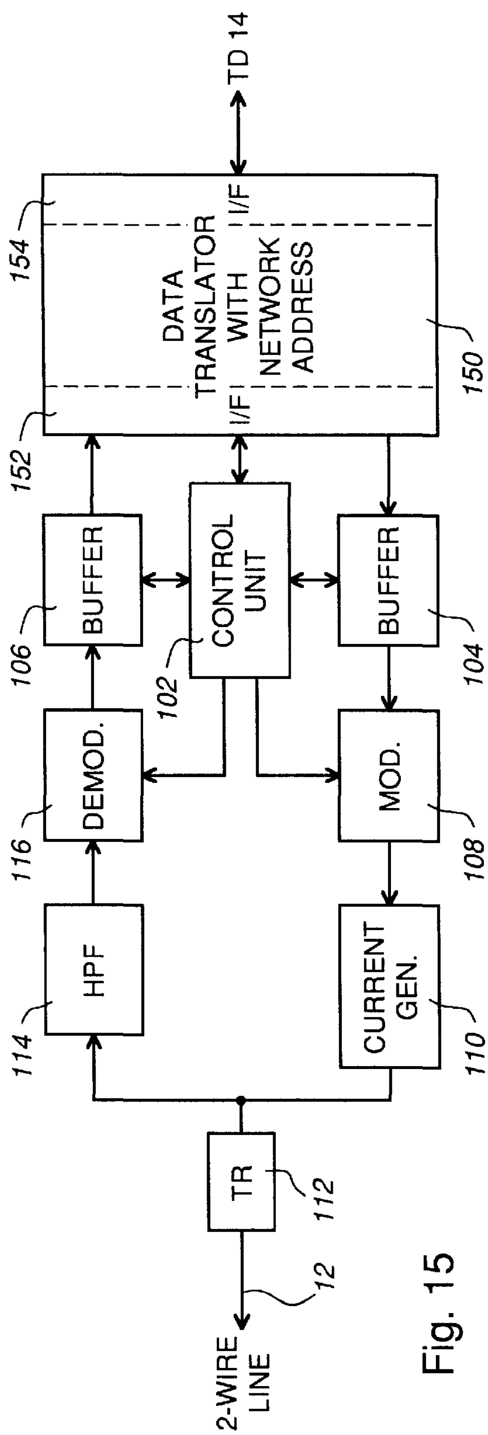

TD 14
154
I/F
DATA TRANSLATOR WITH NETWORK ADDRESS
I/F
152
150
BUFFER
106
CONTROL UNIT
102
BUFFER
104
DEMOD.
116
MOD.
108
HPF
114
CURRENT GEN.
110
TR
112
12
2-WIRE LINE

Fig. 15

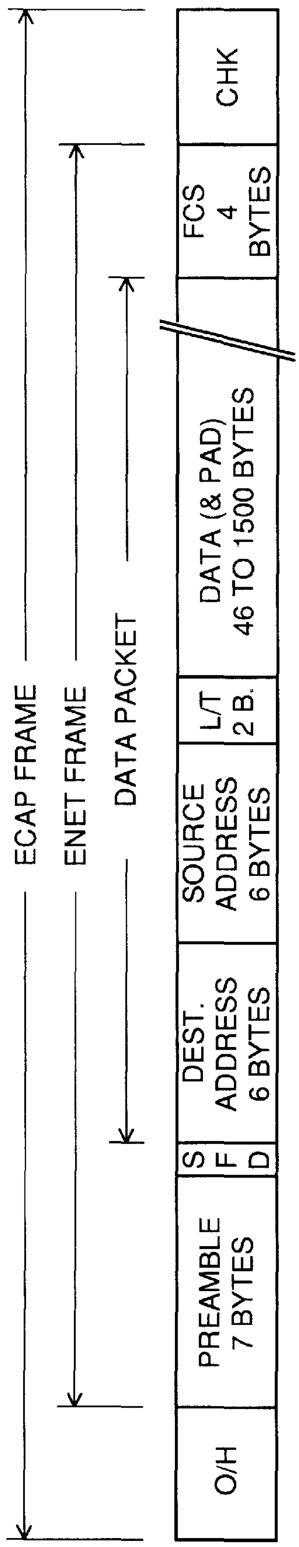


Fig. 9

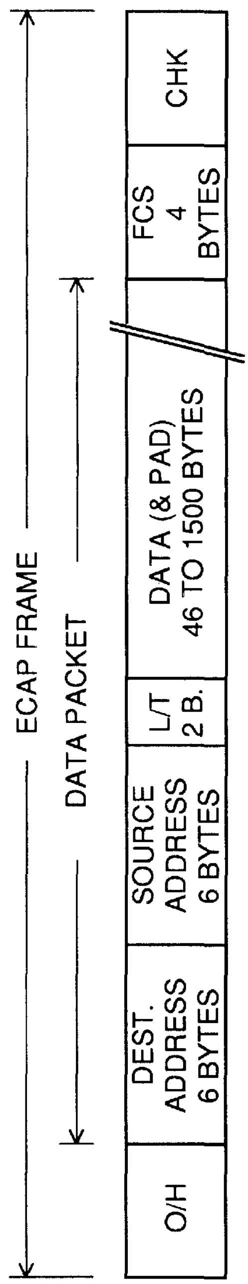


Fig. 10

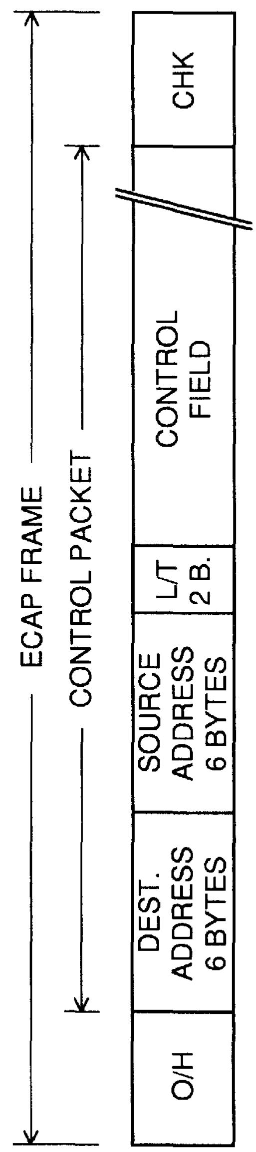


Fig. 11

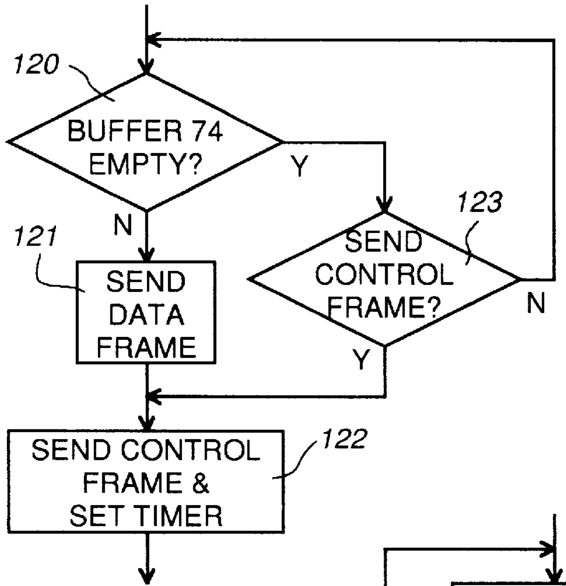

120
BUFFER 74 EMPTY?
Y
N
121
SEND DATA FRAME
123
SEND CONTROL FRAME?
N
Y
SEND CONTROL FRAME & SET TIMER
122

Fig. 12

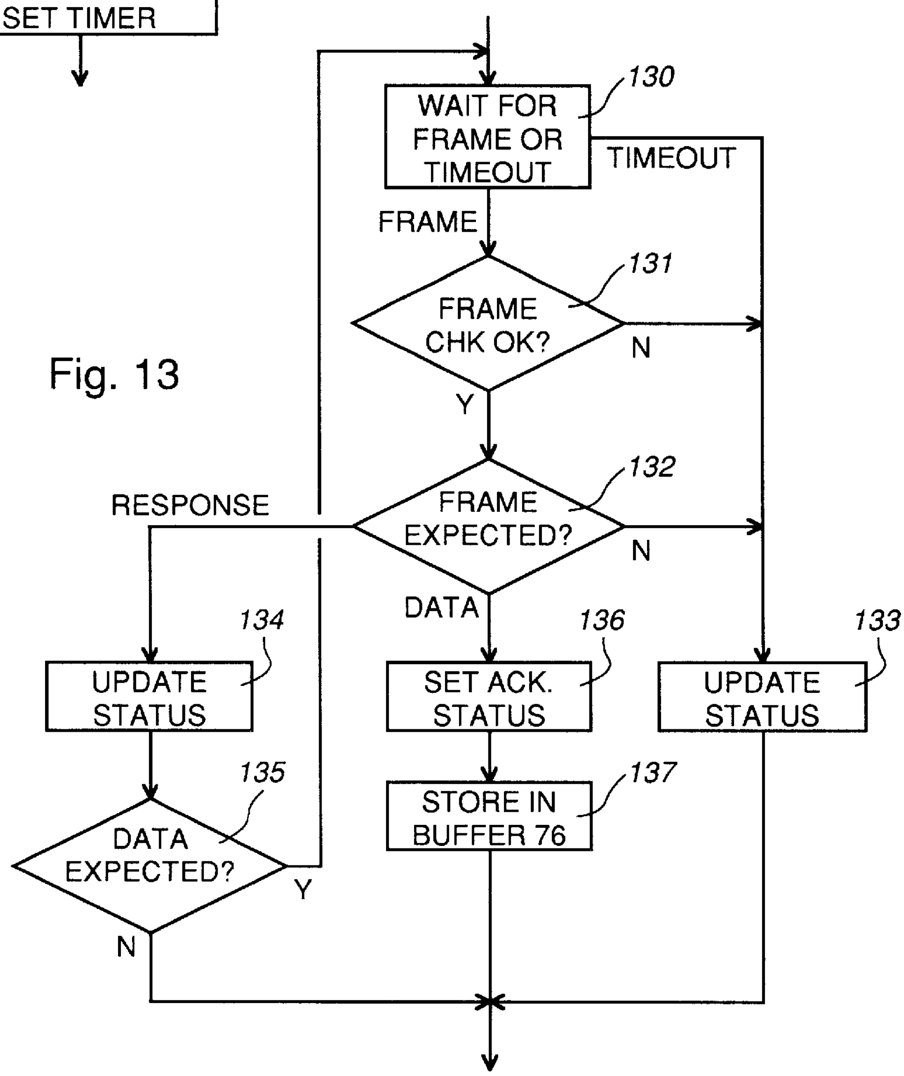

WAIT FOR FRAME OR TIMEOUT
130
TIMEOUT
FRAME
131
FRAME CHK OK?
N
Y
132
FRAME EXPECTED?
RESPONSE
N
DATA
134
UPDATE STATUS
136
SET ACK. STATUS
133
UPDATE STATUS
135
137
STORE IN BUFFER 76
DATA EXPECTED?
Y
N

Fig. 13

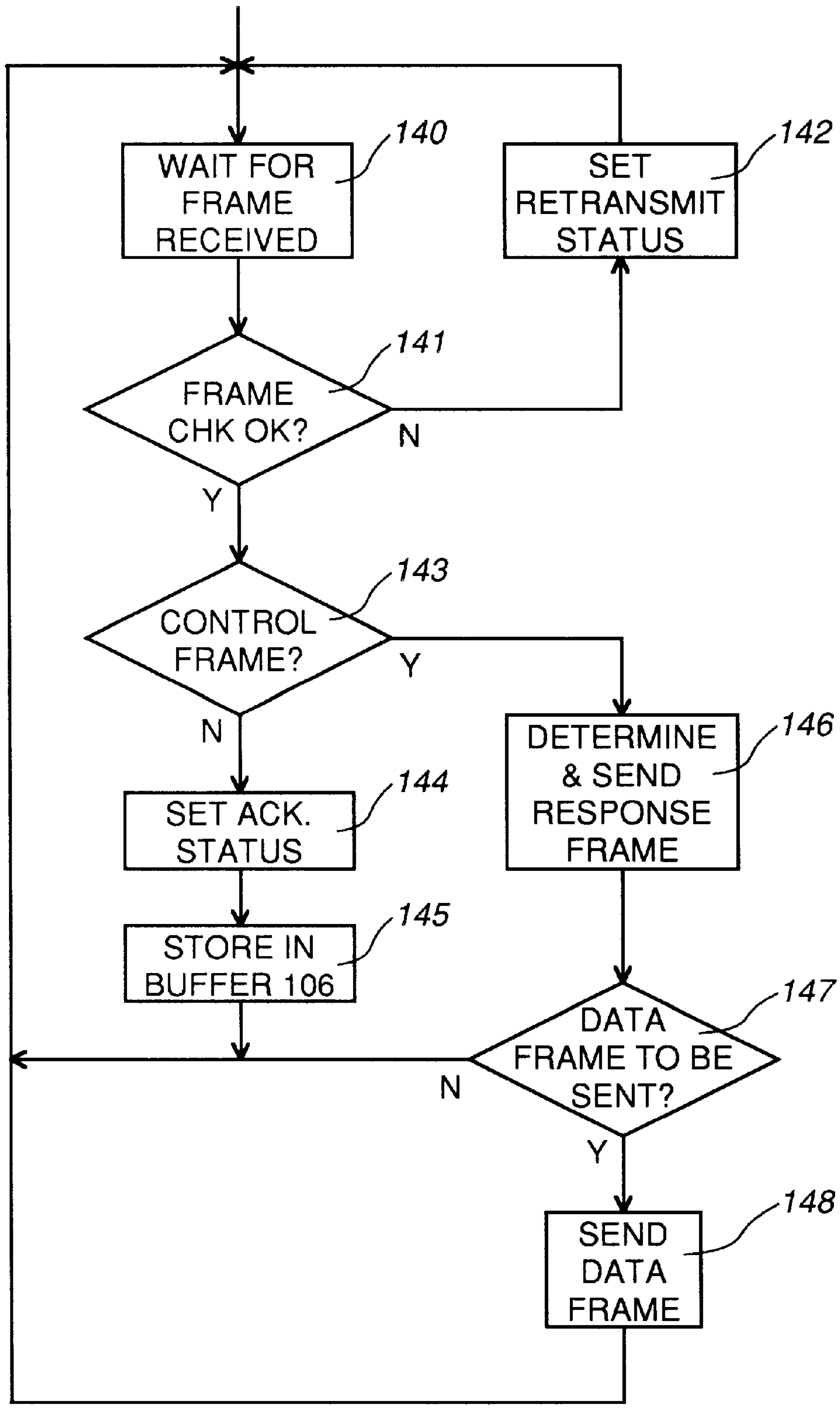

WAIT FOR FRAME RECEIVED
140
SET RETRANSMIT STATUS
142
FRAME CHK OK?
141
N
Y
CONTROL FRAME?
143
Y
N
DETERMINE & SEND RESPONSE FRAME
146
SET ACK. STATUS
144
STORE IN BUFFER 106
145
DATA FRAME TO BE SENT?
147
N
Y
SEND DATA FRAME
148

Fig. 14

INFORMATION NETWORK ACCESS APPARATUS AND METHODS FOR COMMUNICATING INFORMATION PACKETS VIA TELEPHONE LINES

This invention relates to information network access, and is particularly concerned with apparatus and methods for communicating information packets, generally referred to as Ethernet frames, via two-wire lines such as telephone subscriber lines.

BACKGROUND OF THE INVENTION

Computers and related devices are increasingly being connected into networks for communications between the devices. Typically, the networks comprise LANs (local area networks) which provide communications among devices within a relatively small geographical area, different LANs being interconnected via MANs (metropolitan area networks) and WANs (wide area networks). This has resulted in a global computer information network which is generally known as the Internet. The term "Network" is used herein to refer generically to this global computer information network and to any other network of computers and related devices.

Different technologies can be used to facilitate communications on any LAN and throughout the Network, the most common being Carrier Sense Multiple Access with Collision Detection (CSMA/CD) technology. This is documented in IEEE Standard 802.3 entitled "Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications" which has been adopted by the International Organization for Standardization (ISO). The 802.3 Standard is based on the 1985 Version 2 Standard for Ethernet and, although there are some differences including different use of a length/type field, the two Standards are largely interchangeable and can be considered equivalent as far as this invention is concerned. The term "CSMA/CD" is used herein to refer generically to this technology. Using CSMA/CD, packets of data are communicated in frames that are generally referred to as Ethernet frames. This term is also used herein, regardless of whether the frames comply with the 802.3 Standard or the Ethernet Standard (i.e. regardless of the value contained in the length/type field of the frame).

The OSI (Open Systems Interconnection) reference model established by the ISO defines packetized communications protocols in seven layers, of which Layer **1** is the physical layer which is concerned with the physical interfaces between devices and the communications medium, and Layer **2** is the data link layer which is concerned with sending and receiving blocks of data together with information for example for synchronization and error and flow control. For LANs, the data link layer is generally considered as comprising two sub-layers, referred to as the LLC (logical link control) layer and the MAC (medium access control) layer. The LLC layer (Layer **2**) is addressed by IEEE Standard 802.2. The CSMA/CD Standards address communications at the MAC and physical layers (Layers **2** and **1**).

A particularly convenient and popular physical medium for LAN communications is twisted pair wiring as is commonly used for telephone communications. Such wiring typically consists of 0.4 mm to 0.6 mm diameter (26 AWG to 22 AWG) unshielded wires twisted together in pairs in a multipair cable. For example, one of the options for the physical layer documented for CSMA/CD is referred to as

10BASE-T and provides baseband communications at a data rate of 10 Mb/s over twisted pair wiring. The performance specifications are generally met by up to 100 m (meters) of 0.5 mm telephone twisted pair wire without the use of a repeater. Longer wiring lengths are permitted as long as the performance specifications, in particular a maximum delay, are met.

Accordingly, devices that are located relatively close to one another, for example within a building, can be relatively easily connected in a LAN using twisted pair wiring. For CSMA/CD communications via the LAN and for access to the Network, each device is easily equipped with an Ethernet interface card, which is connected via a respective twisted pair of wires to a repeater or CSMA/CD hub, and with TCP/IP (Transmission Control Protocol/Internet Protocol) software that handles the packetized communications at Layers **3** and **4** of the OSI model (Network and Transport Layers, respectively).

Increasingly, access to the Network is required from devices that are relatively distant from existing Network facilities. For example, such devices may be located within residences and small businesses, and they may be isolated computers or they may be connected in a LAN that is not connected to the rest of the Network. Such devices may for example comprise general-purpose computers or specific-purpose devices such as a Network browser, game machine, and/or entertainment device, and may also comprise related and/or ancillary equipment such as workstations, printers, scanners, bridges, routers, etc. that it may be desired to connect to the Network. The generic term "terminal device" and its abbreviation "TD" is used below to embrace all such devices.

It is known to provide for access to the Network from a relatively distant terminal device, or TD, via a communications path between a router on the Network and the distant TD, the communications path typically being constituted by a telephone line.

A simple form of such a communications path is a serial link comprising modem communications via a conventional two-wire telephone line. At Layers **1** and **2** of the OSI model the CSMA/CD communication, which can not be used on the serial link because of its length and characteristics, is replaced for the communication with each distant TD by modem communications via the respective telephone line and a point-to-point protocol, such as PPP (Point to Point Protocol) or SLIP (Serial Link Internet Protocol). Currently, modem communications generally provide a maximum data rate of 28.8 kb/s, and may typically operate in practice at lower, fall-back, data rates such as 19.2 or 14.4 kb/s. Such data rates are increasingly insufficient to meet demands imposed on communications for Network access, in particular for rapid downloading of relatively large amounts of data, e.g. for graphics. In addition, use of such modem communications prevents simultaneous use of the telephone line for telephone communications. Furthermore, such a communications path is set up as a dialled connection via the public switched telephone network (PSTN), which involves the inconvenience to the distant TD user of having to establish the dialled connection and the disadvantage of long connection times via the PSTN.

An alternative form of telephone communications path comprises an ISDN (Integrated Services Digital Network) telephone line. This provides two 64 kb/s B-channels each of which can be used for carrying voice communications or data. A TD can be connected to the ISDN line via a terminal adapter, which can thereby provide a total bit rate of 128

kb/s for data on both B-channels, or 64 kb/s for data on one B-channel simultaneously with digital telephone voice communications on the other B-channel. While this provides a significant increase in data rate compared with using a conventional two-wire telephone line, it requires an ISDN telephone line which, in the relatively limited areas in which it is available, involves additional cost, and the connection still has the disadvantage of being a dialled connection via the telephone network. In addition, a terminal adapter is generally more costly than a modem. Furthermore, even data rates of 64 kb/s or 128 kb/s are likely to be increasingly insufficient with evolution of the Network.

Higher speed telecommunications lines may be available for lease to provide high data rate communications, but these are not economical for TDs in residences and most small businesses. Cable modems have also been proposed for providing Network access via coaxial (coax) or hybrid fiber-coax (HFC) cable television distribution networks that provide bidirectional communications. While such proposals offer the possibility of high data rates, they are also limited to their own serving areas and are likely to involve relatively high costs for both the modem equipment and the ongoing use of the service.

Accordingly, there is an increasing need to facilitate access from terminal devices to the Network at relatively low cost both for equipment and ongoing service, that is not restricted to particular areas, that provides for high data rates, and that desirably does not preempt telephone communications or require long connection times via the PSTN. An object of this invention is to address this need.

SUMMARY OF THE INVENTION

According to one aspect, this invention provides a method of communicating information packets to and from a CSMA/CD (Carrier Sense Multiple Access with Collision Detection) path via a bidirectional communications path, comprising the steps of: coupling a first end of the communications path to the CSMA/CD path via a first modem having a CSMA/CD interface coupled to the CSMA/CD path whereby said information packets are communicated between the CSMA/CD path and the first modem; coupling a second end of the communications path to a second modem; and communicating said information packets between the first and second modems via the communications path using half duplex communications.

The half duplex communications, which can alternatively be considered as time division duplex or time compression multiplex communications, avoid collisions or interference between information packets communicated in the two directions of communication on the communications path by ensuring that the communications in the two directions take place at different times.

Preferably the half duplex communications are controlled by the first modem, the method further comprising the step of communicating control information via the communications path from the first modem to the second modem. The information packets can be communicated by enveloping them in information frames which also comprise error check fields for error checking of at least the enveloped information packets. Information relating to operation of the modems, such as control information from the first modem to the second modem and response information from the second modem to the first modem, can be included in at least some of the information frames and/or in further frames which comprise this information and an error check field for error checking of at least this information.

Preferably each information packet communicated between the modems via the communications path comprises at least address, length, and data fields of an Ethernet frame communicated via the CSMA/CD path; it desirably also comprises a frame check sequence of the respective Ethernet frame, and may further comprise a preamble and start frame delimiter of an Ethernet frame.

Advantageously, the communications path comprises a two-wire telephone subscriber line and the modems communicate said information packets via the line at frequencies greater than telephone signal frequencies, the method further comprising the steps of communicating telephone signals via the line and, at each end of the line, combining telephone signals and information packets to be communicated via the line, and separating telephone signals and information packets communicated via the line, using a diplexer.

The method can further comprise the step of multiplexing the first modem for communicating information packets between the first modem and a plurality of second modems via respective two-wire (e.g. telephone subscriber) lines.

The method can further comprise the steps of monitoring errors in communicating said information packets between the first and second modems via the communications path, and determining operations of the first and second modems in dependence upon monitored errors. The step of determining operations of the modems in dependence upon monitored errors can comprise varying a signal bandwidth and/or a modulation method of the modems. This enables an optimum rate to be achieved for communicating information packets via any particular two-wire line.

The second modem can have a CSMA/CD interface, the method further comprising the step of communicating said information packets between the second modem and a second CSMA/CD path via the CSMA/CD interface of the second modem.

Another aspect of the invention provides a method of providing communications with a CSMA/CD network via a bidirectional communications path, comprising the steps of: at a first end of the communications path, providing a CSMA/CD interface to the network, buffering information packets received from the network via the interface in a first buffer, supplying information packets from the first buffer to the communications path, and supplying control information to the communications path; at a second end of the communications path, buffering information packets received via the communications path in a second buffer, receiving the control information from the communications path, buffering information packets to be supplied via the communications path to the network in a third buffer, and supplying information packets from the third buffer to the communications path in dependence upon the control information; and at the first end of the communications path, supplying information packets received via the communications path to a fourth buffer, and supplying the information packets from the fourth buffer to the network via the interface; wherein the control information and the dependence on the control information for supplying information packets from the third buffer to the communications path are arranged to avoid collisions on the communications path between information packets communicated from the first buffer to the second buffer and information packets communicated from the third buffer to the fourth buffer.

This method can further comprise the steps of monitoring fills of at least some of the buffers, and varying a ratio of information packets communicated from the first buffer to the second buffer to information packets communicated

from the third buffer to the fourth buffer in dependence upon the monitored fills. This enables a variable ratio of information packets communicated in the two directions of communication to be achieved dynamically to provide an optimum flow of information packets at all times.

Preferably in this method the information packets are communicated via the communications path as modulated signals between modems at the first and second ends of the communications path.

This method can further comprise the steps of providing a second CSMA/CD interface to a second CSMA/CD path at the second end of the communications path and communicating information packets between the second and third buffers and the second CSMA/CD path via the second CSMA/CD interface. The method can then further comprise the step of jamming the second CSMA/CD path from the second CSMA/CD interface in response to filling of the third buffer. The jamming of the second CSMA/CD path is detected as a collision by devices connected to that path, causing retransmission of information packets that for the time being can not be received by the third buffer.

The invention also provides a method of coupling a terminal device to a CSMA/CD network via a two-wire telephone subscriber line, comprising the steps of: coupling a first end of the line to the network via a first modem including a CSMA/CD interface to the network; coupling a second end of the line to the terminal device via a second modem including an interface to the terminal device; communicating information packets downstream from the network to the terminal device via the CSMA/CD interface, first modem, line, second modem, and terminal device interface; communicating control information downstream from the first modem to the second modem; and communicating information packets upstream from the terminal device to the network via the terminal device interface, second modem, line, first modem, and CSMA/CD interface under control of the control information at times to avoid interference with the information packets and control information communicated downstream.

A further aspect of the invention provides a network access arrangement for providing communications with a CSMA/CD path via a communications path, comprising: a first unit for coupling a first end of the communications path to the CSMA/CD path, the first unit comprising a CSMA/CD interface for connection to the CSMA/CD path, a buffer for buffering information packets supplied from the CSMA/CD path via the CSMA/CD interface for supply to the communications path, a buffer for buffering information packets received from the communications path for supply to the CSMA/CD path via the CSMA/CD interface, and a control unit; and a second unit for connection to a second end of the communications path, the second unit comprising a buffer for buffering information packets received via the communications path, a buffer for buffering information packets to be supplied to the communications path, and a control unit; wherein the control units of the first and second units are arranged to exchange control information via the communications path for communicating information packets bidirectionally via the communications path between the buffers of the first and second units in a half duplex manner.

Conveniently the first and second units comprise modems for communicating the information packets and control information as modulated signals via the communications path. Preferably the modems of the first and second units are arranged to produce the modulated signals at frequencies greater than telephone signal frequencies, and each of the

first and second units includes a frequency diplexer via which the units are coupled to the communications path, the diplexers having further connections for telephone equipment for simultaneous communications of telephone signals via the communications path.

The invention further provides a modem for communicating information packets of Ethernet frames via a two-wire line, comprising: a control unit; an interface for supplying and receiving information packets of Ethernet frames; a first buffer for receiving and buffering information packets from the interface; a modulator responsive to the control unit for supplying modulated signals comprising information packets from the first buffer to a two-wire line; a demodulator for demodulating modulated signals received via the two-wire line to produce demodulated signals; and a second buffer for receiving and buffering information packets contained in the demodulated signals for supply to the interface; wherein the control unit is arranged to produce or respond to control information in the modulated signals on the two-wire line to control the modulator to supply modulated signals to the two-wire line only at times when modulated signals are not being received via the two-wire line.

The interface can comprise a CSMA/CD interface to a CSMA/CD path, or it can comprise a direct interface to a terminal device.

The control unit can be arranged to produce said control information for said modulated signals on a plurality of two-wire lines, the modem comprising respective first and second buffers for buffering information packets in respect of each of the plurality of lines, the modem further comprising a demultiplexer controlled by the control unit to couple any of the plurality of two-wire lines to the demodulator, and a multiplexer controlled by the control unit to couple the modulator to any of the plurality of two-wire lines.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be further understood from the following description with reference to the accompanying drawings, in which:

FIG. **1** schematically illustrates a known Network access arrangement;

FIG. **2** illustrates the known format of an Ethernet frame;

FIG. **3** schematically illustrates a Network access arrangement in accordance with an embodiment of this invention;

FIG. **4** schematically illustrates a Network access arrangement, providing for simultaneous telephone communications, in accordance with another embodiment of this invention;

FIG. **5** schematically illustrates a diplexer used in the arrangement of FIG. **4**;

FIG. **6** shows a graph illustrating frequency characteristics related to the arrangement of FIG. **4**;

FIG. **7** schematically illustrates a master modem provided in the Network access arrangements of FIGS. **3** and **4**;

FIG. **8** schematically illustrates a slave modem provided in the Network access arrangements of FIGS. **3** and **4**;

FIGS. **9** to **11** illustrate frame formats that can be used in Network access arrangements in accordance with embodiments of the invention;

FIGS. **12** to **14** are flow charts with reference to which operation of the master and slave modems is described; and

FIG. **15**, which is on the same sheet as FIG. **8**, schematically illustrates a combined unit which replaces a slave modem and Ethernet interface provided in the arrangement of FIG. **3**.

DETAILED DESCRIPTION

FIG. **1** illustrates elements of a known arrangement for access from a subscriber to the Network **10** via a conventional two-wire telephone line **12**. Subscriber equipment includes a terminal device (TD) **14** which for example is constituted by a personal computer (PC), and a modem **16** connected to the line **12** and for example providing a maximum data rate of 28.8 kb/s. Although shown separately from the TD **14**, the modem **16** can instead be incorporated therein. The modem **16** communicates with a modem in a pool of dial-up modems **18** with a dialled connection which is established in well-known manner via the PSTN **20** to which the telephone line **12** is connected. The modems in the modem pool **18** are connected via an Ethernet interface (ENET I/F) **22** to a router **24** which is connected to the Network **10** and hence can be considered to be a part of the Network, the Network **10** generally being considered to include all of the terminal devices connected to it.

An upper part of FIG. **1** illustrates protocols in accordance with which the arrangement operates. TCP/IP operates at OSI Layers **3** and **4** end-to-end throughout the entire Network and access arrangement, with TCP/IP software running on the TD **14**. At the MAC layer of OSI Layer **2**, communications in the access arrangement between the Ethernet interface **22** and the TD **14** operate in accordance with a point-to-point protocol such as PPP or SLIP, and communications between the Ethernet interface **22** and the Network **10**, and within the Network **10**, comprise Ethernet frames as described below with reference to FIG. **2**. These frames can be carried in a wide variety of forms and via various physical media, for example as the Ethernet frames themselves on a CSMA/CD LAN, in ATM (asynchronous transfer mode) cells, in SONET (synchronous optical network) formats, and so on. For communications between the Network **10** and the TD **14**, the router **24** converts between the Ethernet frames of the Network and the serial communications on the line **12** between the modems **16** and **18**.

A generally similar arrangement to that of FIG. **1** is provided in the event that the telephone line is an ISDN line, except that the modem **16** is replaced by an ISDN terminal adapter and communications on the line are digital at a rate that can be 64 or 128 kb/s.

FIG. **2** illustrates the Ethernet frame at the MAC layer. It consists of, in order, a preamble field of 7 bytes or octets (8 bits) of alternating 1s and 0s starting with a 1; a start frame delimiter (SFD) field of 1 byte having the sequence 10101011; a destination address field of 6 bytes; a source address field of 6 bytes; a length or type field of 2 bytes described further below; a data field of 46 to 1500 bytes, and a frame check sequence (FCS) field of 4 bytes or octets constituted by a CRC (cyclic redundancy check) of the data packet constituted by the address, length or type, and data fields. Data of less than 46 bytes in a frame is padded to the minimum data field size of 46 bytes. In accordance with the 802.3 Standard, the length or type field represents the length of data in the data field up to the maximum of 1500 bytes. In accordance with the Ethernet Standard, the length or type field is a value greater than 1500 that represents the type of data packet, and IP data packets are identified by one specific type value in this field. Thus the two Standards are different but inter-operable in this respect. It follows from this format that each frame comprises a data packet of from 60 to 1514 bytes, together with overhead (preamble, SFD, and FCS fields) of 12 bytes.

In accordance with the CSMA/CD Standards, the bits of each Ethernet frame are communicated using Manchester coding (a 1 bit is encoded as a 01 sequence, and a 0 bit is encoded as a 10 sequence, in each case with a transition in the middle of the bit period) at a predetermined data rate which is typically 10 Mb/s. Any terminal device connected to a CSMA/CD LAN can transmit a frame to the LAN (Multiple Access) in accordance with a contention scheme which is summarized by the following steps:

1. Monitor the LAN (Carrier Sense).
2. When the LAN is idle, transmit.
3. While transmitting, monitor the LAN for a collision (Collision Detection) by comparing transmitted bits with what is received from the LAN.
4. When a collision is detected, continue transmitting for a short period so that all TDs on the LAN detect the collision (this is referred to as jamming). Wait a random period of time determined by a binary exponential back-off algorithm, then return to step 1 for retransmission.

The minimum and maximum Ethernet frame size, predetermined data rate, and characteristics and lengths of segments of the LAN are inter-related in a manner that ensures effective operation of this contention scheme. For a 10BASE-T LAN using twisted pair wiring, as explained in the background of the invention this results in a maximum segment length of the order of 100 meters.

The two-wire telephone line **12** in the arrangement of FIG. **1** is constituted by twisted pair wiring, but has a length which is invariably much greater than 100 meters. Typically the length may be a maximum of about 5500 meters, with an average length for telephone lines in North America of the order of 1700 meters. These lengths are much greater than the approximate 100 meter maximum for a 10BASE-T LAN, and propagation delays make it impossible for the contention scheme outlined above to operate over such distances of twisted pair wiring. Even if this were not the case, signal attenuation over these distances of twisted pair wiring would make it very difficult to provide any reliable detection of collisions. Accordingly, it is not practical to use CSMA/CD on the telephone line **12**. Instead, the serial link point-to-point protocols are used in conjunction with the modems **16** and **18** as discussed above to provide Network access, with the data rate and other limitations discussed in the background of the invention.

FIG. **3** illustrates a Network access arrangement in accordance with an embodiment of this invention which is described first below, and also illustrates variations of this which are described subsequently below.

In FIG. **3**, a TD **14** of a subscriber is again connected to the Network **10** via a two-wire telephone subscriber line **12** which in this arrangement, as in the arrangement of FIG. **1**, is not being used for telephone communications. The TD **14** in this arrangement is connected to the line **12** via an Ethernet interface (ENET I/F) **30** and a modem **32**. The interface **30** is a conventional Ethernet interface which, although shown separately from the TD **14** in FIG. **3**, can be conveniently incorporated into the TD **14** either on a plug-in card or as a permanent part of the TD **14**. The interface **30** is the same as would be provided for connecting the TD **14** directly to a CSMA/CD LAN. The modem **32** has a form for example as described in detail below with reference to FIG. **8**, and has an Ethernet interface that is connected to the interface **30**, and a two-wire line interface that is connected to the line **12**. Conveniently, the connection between the Ethernet interface **30** and the modem **32** is a 10BASE-T connection using twisted pair wiring. The modem **32** is referred to below as a slave modem as explained further below. The Ethernet interface **30** provides a Network

address for the TD **14** as is well known. Similarly, the Ethernet interface within the modem **32** provides this with a Network address. Although the slave modem **32** is shown separately from the interface **30** and the TD **14**, the modem **32** can be physically combined with the Ethernet interface **30** for example as described below with reference to FIG. **15**, and can be incorporated into the TD **14**.

At its other end, for example at a PSTN central office (CO) or remote terminal (RT), the two-wire telephone line **12** is connected to a modem **34** which is referred to as a master modem and an example of which is described below with reference to FIG. **7**. The modem **34** also has a 10BASE-T Ethernet interface which provides the master modem with a Network address. This interface is connected via twisted pair wiring **36**, an Ethernet switch **38**, and a router **40** to the rest of the Network **10** in known manner. As is well known, functions of the switch **38** and router **40** can be combined in a single device referred to as a brouter.

An upper part of FIG. **3** illustrates, in a similar manner to FIG. **1**, protocols in accordance with which the Network access arrangement operates. As in the arrangement of FIG. **1**, TCP/IP operates at OSI Layers **3** and **4** end-to-end throughout the entire Network and access arrangement, with TCP/IP software running on the TD **14**. At the MAC layer, communications within and between the Network **10**, router **40**, switch **38**, and master modem **34** comprise Ethernet frames as described above. Similarly, communications between the slave modem **32** and the Ethernet interface **30** comprise Ethernet frames as described above, and the TD **14** operates in exactly the same known manner as it would if the interface **30** were connected directly to a LAN.

Communications between the master modem **34** and the slave modem **32** are carried out in accordance with a new point-to-point protocol which uses collision avoidance to communicate Ethernet frames between the modems. This protocol is described below and for convenience is referred to herein as ECAP (Ethernet frame Collision Avoidance Protocol). It is observed that this protocol operates only between the modems **32** and **34**, and hence need not be known to, and does not change the operation of, the TD **14** or the rest of the Network **10**. The protocol and modems simply serve to replace a direct (short-distance) connection between the interface **30** and the twisted pair wiring **36** by a remote connection via the (much greater distance) two-wire line **12**. Thus although as described here the line **12** is a telephone subscriber line, it can be appreciated that the same arrangement of master and slave modems operating in accordance with this new protocol can be used to communicate Ethernet frames via any twisted pair wiring which is too long to permit conventional 10BASE-T or similar LAN interconnections.

FIG. **3** also illustrates a management device **42**, for example a computer, coupled to the Ethernet switch **38** for providing operations, administrations, management, test, and other functions relating to the communications in known manner. In order to provide communications via multiple lines **12** to multiple subscribers, preferably the master modem **34** contains multiplexing functions as described below with reference to FIG. **7**, and other master modems, one of which is illustrated in FIG. **3** and referenced **34'**, are connected to the switch **38** similarly to the modem **34**.

At the subscriber, one or more further arrangements of a slave modem **32'**, Ethernet interface **30'**, and TD **14'** can be similarly connected to the same two-wire line **12** as shown by a dashed line connection **44**. Alternatively (or in addition), and generally more desirably, as shown by a dashed line connection **46** the 10BASE-T connection of the slave modem **32** can be connected to a bridge **48** of known form, to which a plurality of TDs **14"**, can be connected via their respective Ethernet interfaces (EI/Fs) in known manner to provide a subscriber LAN. These arrangements can be extended as desired in known manner.

It can be seen from the above description that embodiments of the invention are centered on the arrangement and functioning of the modems **32** and **34**. Before describing embodiments of these in detail, a further Network access arrangement is described below with reference to FIG. **4**. This further arrangement illustrates that the communications on each line **12** can comprise not only the data communications for the Network as described herein but also conventional telephone communications.

Referring to FIG. **4**, this illustrates the master and slave modems **34** and **32** respectively, with 10BASE-T interfaces to twisted pair wiring **36** and **46** respectively as described above, coupled via a two-wire subscriber line **12** which also serves for conventional telephone connections between a subscriber telephone **51** and a telephone CO or RT **50** connected to the PSTN. To this end, a passive diplexer **52** is provided at each end of the two-wire line **12**, the two diplexers **52** conveniently having the same form and being for example as described below with reference to FIG. **5**. Thus at a head end of the line **12** the CO or RT **50** and the master modem **34** are connected via a diplexer **52** to the line **12**, and at a subscriber end of the line **12** the subscriber telephone **51** and the slave modem **32** are connected to the line **12** via a diplexer **52**. As also shown in FIG. **4**, the master modem **34** can be multiplexed for other telephone subscriber lines **12'** to which it is similarly connected via respective diplexers **52'**. It can be appreciated that diplexers can be similarly provided in the arrangement of FIG. **3** to permit simultaneous telephone and Network communications.

FIG. **5** illustrates a simple form of the diplexer **52**, which comprises a d.c. and low pass filter (LPF) **54** between a two-wire connection to the line **12** and a two-wire connection to the telephone **51** or CO or RT **50**, and a d.c. isolator and high pass filter (HPF) **56** between the two-wire connection to the line **12** and a two-wire connection to the modem **32** or **34**. As illustrated in FIG. **5**, the LPF **54** can comprise one or more balanced filter sections comprising series inductors (which pass the telephone loop current) and shunt capacitors, and the HPF **56** can comprise two series capacitors having a capacitance such that they do not represent a significant load to the line **12**. More complicated forms of diplexer **52** can be provided as desired.

The graph in FIG. **6** illustrates the low frequency spectrum **60** of analog telephony signals, and two high frequency spectra **62** and **64** for Network communications. A desirable response **66** for the LPF **54** of the diplexer **52** separates the low frequency telephony signals on the two-wire line **12** from the Network communications signals on the same line **12**. It can be seen from this illustration that the telephony and Network communications signals occupy substantially different frequency bands and hence are easily separated by the diplexers **52**.

In FIG. **6**, the spectra **62** and **64** relate to two different signal bandwidths which can be used for the Network communications. For example, the relatively wide bandwidth spectrum **62** can correspond to a modulation method with a symbol or clock rate of 3 MHz, and the relatively narrower bandwidth spectrum **64** can correspond to a modulation method with a symbol or clock rate of 300 kHz. Other signal bandwidths, not shown, can be similarly provided. The use of different bandwidths and modulation methods is described further below.

FIG. **7** illustrates a form of the master modem **34**, including optional but desirable multiplexing for a plurality of two-wire lines. The master modem includes an Ethernet interface **70** of known form providing a 10BASE-T connection to the twisted pair wiring **36** and providing (for example from a read-only memory within the interface **70**) a Network address for the master modem. The interface **70** is connected to a control unit **72** of the master modem, to the input of a FIFO (first in, first out) buffer **74** for buffering downstream Ethernet frames supplied from the Network via the wiring **36** and the interface **70**, and to the output of a FIFO buffer **76** for supplying upstream Ethernet frames via the interface **70** and the wiring **36** to the Network. An output of the buffer **74** is coupled via a modulator **78** and a downstream demultiplexer **80** (constituted by switches) to a respective one of the multiplexed two-wire lines **12** via a respective isolating transformer (TR) **82**, the output of the modulator **78** providing a matched termination for the line **12**. An upstream multiplexer **84** (constituted by switches) has inputs also coupled to the lines **12** via the transformers **82**, and has an output coupled via a high pass filter (HPF) **86** which provides a matched termination for the respective line **12** to which it is connected via the multiplexer **84**. An output of the HPF **86** is connected to an input of a demodulator **88** having an output connected to an input of the buffer **76**. The transformers **82** can also provide a balun function between the balanced lines **12** and the demultiplexer **80** and multiplexer **84**.

The demultiplexer **80** and multiplexer **84** are addressed by the control unit **72** via address lines **90** and **92** respectively to provide downstream frames to and to receive upstream frames from respective ones of the lines **12**. The addresses on the lines **90** and **92** are generally different for efficient data flow in the downstream and upstream directions, but they can be the same for example for loopback testing of a slave modem **32**. To provide different logical buffers for frames in the buffers **74** and **76** associated with the respective lines **12**, the buffers **74** and **76** are also addressed via the address lines **90** and **92** respectively. A store **94** is also addressed with the upstream multiplexer address on the lines **92** to provide to the demodulator **88** stored data, such as echo coefficients and signal amplitude level, relating to the respective line **12** to facilitate fast acquisition (recognition of the preamble of a frame) by the demodulator **88**. A store **95** is similarly addressed with the downstream demultiplexer address on the lines **90** to provide to the modulator **78** stored data to determine a signal transmission level and possibly frequency characteristics for the respective line **12**. Information for the stores **94** and **95** is determined, and the stores are updated, by the control unit **72** in known manner. Control lines **96** and **98** are provided between the control unit **72** and the modulator **78** and demodulator **88** respectively for communicating control information.

FIG. **8** illustrates a complementary form of a slave modem **32**. The slave modem includes an Ethernet interface **100** of known form providing a 10BASE-T connection to the twisted pair wiring **46** and providing (for example from a read-only memory within the interface **100**) a Network address for the slave modem. The interface **100** is connected to a control unit **102** of the slave modem, to the input of a FIFO buffer **104** for buffering upstream Ethernet frames supplied from the TD via the wiring **46** and the interface **100**, and to the output of a FIFO buffer **106** for supplying downstream Ethernet frames via the interface **100** and the wiring **46** to the TD. An output of the buffer **104** is coupled via a modulator **108**, a current generator **110**, and an isolating transformer **112** to the two-wire line **12**. The transformer **112**, which can also provide a balun function for the balanced line **12**, is also coupled via a high pass filter **114** and a demodulator **116** to an input of the buffer **106**. The current generator **110** provides a high output impedance to avoid loading of the line **12**, and the HPF **114** provides a matched termination of the line **12**, so that these can both be connected to the line **12** without any switching. This enables loopback testing of the line **12** from the control unit **102**. Control lines are provided between the control unit **102** and the buffers **104** and **106**, modulator **108**, and demodulator **116**.

It can be appreciated that, apart from the functions related to the multiplexing and switching for a plurality of lines **12**, and the operation of the modems as described below, the master modem **34** and the slave modem **32** are similar, and the arrangement of the slave modem shown in FIG. **8** could also be used as a master modem for a single line **12**.

In each of the modems **32** and **34** the modulator; demodulator, and related functions are conveniently implemented in known manner using one or more DSPs (digital signal processors) with analog-digital conversion in known manner. DSPs can be conveniently controlled to provide an arbitrary number of different signal bandwidths for example as illustrated by the spectra **62** and **64** in FIG. **6**. Conveniently the DSPs provide a common lower frequency limit of about 10 kHz for all of the signal bandwidths as shown in FIG. **6**, with the different bandwidths being determined by the symbol or clock rate as described above. The particular modulation method that is used is relatively arbitrary, but conveniently the DSPs in the modems are programmed to select any of a plurality of modulation methods, for example 16QAM (quadrature amplitude modulation), QPSK (quadrature phase shift keying), and BPSK (binary phase shift keying), providing different numbers of bits per symbol. These particular methods and numbers are given only by way of example, and other modulation methods, such as VSB (vestigial sideband), carrierless amplitude-phase, and DMT (discrete multi-tone) modulation, may be used instead, numerous different numbers of bits per symbol may be used, and the signal bandwidths may be arbitrarily defined (e.g. with different low-frequency cut-offs) as desired.

The master and slave modems communicate Ethernet frames downstream (from the master modem **34** to the slave modem **32**) and upstream (from the slave modem **32** to the master modem **34**) in a manner described in detail below. Briefly, this communication involves half-duplex transmission using a collision avoidance protocol (ECAP) in which the master modem **34** has priority and control over the slave modem **32**. Thus the master modem **34** determines when to send information downstream via the line **12**, and informs the slave modem when it is permitted to send information upstream via the line **12**. To facilitate these communications, the information sent via the line **12** comprises not only the data packets of Ethernet frames for Network communications but also control packets downstream and response packets upstream between the master and slave modems. These packets are incorporated into ECAP frames examples of which are described below with reference to FIGS. **9** to **11**. The control units **72** and **102** in the master and slave modems perform the necessary conversions between the Ethernet frames and ECAP data frames, and generate and respond to the ECAP control and response frames.

FIG. **9** illustrates an ECAP data frame which comprises overhead information O/H, followed by an Ethernet frame in exactly the same form as described above with reference to FIG. **2**, followed by a check sequence CHK. The O/H field for example consists of a few bytes comprising a preamble

and start-of-frame (SOF) indication of a suitable form for the modulation method in use by the master and slave modems, possibly followed by other information such as an ECAP frame sequence number for frame identification in known manner (e.g. for identifying frames for acknowledgement or retransmission). The check sequence CHK conveniently comprises a CRC sequence which can be produced in exactly the same manner as the FCS field of the Ethernet frame, the CRC operating on all of the information in the ECAP frame following the SOF indication up to and including the FCS at the end of the Ethernet frame. Thus as shown in FIG. **9** the Ethernet frame is enveloped, intact and without any change, within the ECAP frame.

Alternatively, as illustrated in FIG. **10**, the preamble and SFD fields can be stripped from the Ethernet frame and only the remainder of the Ethernet frame (i.e. the data packet and FCS field) incorporated into the ECAP frame between the overhead field O/H and the check sequence CHK. In this case the preamble and SFD fields of the Ethernet frame are stripped for example by the control unit of whichever of the master and slave modems **34** and **32** is sending the frame, and is reinserted by the control unit of the receiving one of the modems **34** and **32** for forwarding the Ethernet frame to the respective Ethernet interface. This reduces slightly the amount of information to be transmitted via the line **12**. Further reductions are possible if for example the pad, used for increasing data packets of less than **46** bytes to the minimum data field size of an Ethernet frame, can also be identified, stripped prior to sending the remainder of the frame between the modems **34** and **32**, and reinserted at the receiving modem. However, it may be more desirable for the modems **34** and **32** always to communicate the entire data packet and FCS field of each Ethernet frame intact, to avoid risk of corrupting the Ethernet frame contents.

Thus whereas transmission of undersized frames is not possible in a CSMA/CD arrangement because of the nature of the contention scheme (they are generally interpreted as collisions), in this ECAP scheme collisions are avoided by the protocol between the master and slave modems so that short frames are not only permitted but can be desirable because they reduce the amount of information that must be communicated via the line **12**.

To this end, FIG. **11** illustrates an ECAP control frame comprising a control packet to be communicated from the master modem **34** to the slave modem **32**. The control frame comprises an initial overhead field O/H as described above, followed by a control packet described below, and the check field CHK providing a CRC sequence for all of the information in the ECAP frame following the SOF indication up to the end of the control packet. The control packet comprises destination and source address fields, a length/type field L/T, and a control field which is generally much shorter than the minimum 46 byte data field of an Ethernet frame and whose length is given by the contents of the field L/T. For such a control packet the destination and source addresses are the Network addresses of the slave modem **32** and the master modem **34**, respectively.

Conversely, an ECAP response frame can have the same form as the control frame shown in FIG. **11**, except that it contains a response field instead of the control field and the destination and source addresses are exchanged because the response frame is communicated from the slave modem **32** to the master modem **34**.

Other ECAP frame formats can alternatively be provided to suit particular situations; for example for convenience or simplicity the control and response frames can have a fixed size and can be the same size as a data frame containing a minimum-size data packet. In addition, although as described here by way of example the control frames are separate from the data frames, control information can instead be incorporated into the ECAP data frames, desirably keeping the enveloped Ethernet frame contents intact, for example as an additional part of the overhead field O/H or between the CRC fields FCS and CHK.

The following description of an example of the collision avoidance protocol, with reference to FIGS. **12** to **14**, assumes for simplicity and clarity that the master modem **34** typically sends a single data frame followed by a control frame downstream, and then waits for a response from the slave modem **32**, and that the slave modem waits for these downstream frames and then typically sends a response frame followed by a single data frame upstream. It also assumes for simplicity that there is only one slave modem **32** connected to the line **12**. Various modifications and extensions of this protocol, for example to accommodate multiple slave modems **32** connected to the same line **12**, can be contemplated and some variations are described later below.

FIG. **12** illustrates a downstream transmitting flow chart for the master modem **34**, and FIG. **13** illustrates an upstream receiving flow chart for the master modem **34**, the master modem **34** being assumed here simply to alternate between the transmitting and receiving states for communications with a single slave modem **32**. As already described, the master modem **34** can provide multiplexed operations for a plurality of slave modems, so that in practice the transmitting and receiving processes can take place simultaneously and independently in a multiplexed manner for a plurality of slave modems. FIG. **14** illustrates a downstream receiving and upstream transmitting flow chart for the slave modem **32**. The operations in the modems in each case take place under the control of the respective control unit **72** or **102**, and the master and slave modems differ in the manner in which these units operate as described below.

Referring to FIG. **12**, in the transmitting sequence of the master modem **34** its control unit **72** initially determines in a decision **120** whether the downstream buffer **74** (for the respective line **12** and slave modem **32**) is empty. If not, i.e. if there is at least one Ethernet frame to be sent from the buffer **74**, then at a block **121** the next frame to be sent downstream from the buffer **74** is transmitted in an ECAP data frame as described above. At a block **122** the control unit **72** then sends a control frame as described above, and sets a timer for a response from the slave unit. In the event that the buffer **74** is empty as determined in the decision **120**, then in a decision **123** the control unit **72** determines whether or not to send a control frame, if so proceeds to the block **122** to send a control frame, and if not returns to the start of the transmitting sequence. The decision **123** whether or not to send a control frame may depend upon various parameters which are monitored by the control unit **72**, such as the fill state of the upstream receiving buffer **76**, the state of the slave modem and the fill state of its upstream transmitting buffer **104**, and the time since the previous control frame was sent to the slave modem. The contents of the control frame can comprise, for example, a request (poll) for the slave modem to transmit a frame of data upstream, a request for retransmission by the slave modem of a previous frame that has not been received correctly as determined by its check field CHK, control information such as operating parameters for the slave modem, and/or a request for status information, such as the fills of the buffers **104** and **106**, from the slave modem.

Referring now to FIG. **14**, at a block **140** the control unit **102** of the slave modem **32** initially waits for a frame to be

received from the master modem **34**. This waiting, and the subsequent operation of the slave modem in response to a received frame and operation of the master modem, ensures that collisions on the line **12** are avoided by giving control of the ECAP frames on the line **12** entirely to the master modem **34**. In response to receipt of a downstream frame from the master modem **34**, the control unit **102** of the slave modem determines in a decision **141** from the field CHK whether the frame has been received properly and, if not, at a block **142** sets a status flag to request retransmission of the frame and returns to the wait block **140**. If the frame has been properly received the control unit **102** proceeds to a decision **143**.

In the decision **143** the control unit **102** determines whether or not the destination address in the received frame is the address of the slave modem, and hence whether the frame is a control frame or a data frame. If the frame is determined to be a data frame, then in a block **144** the control unit **102** sets a status flag for acknowledgement of the frame, and in a block **145** the data frame is stored in the buffer **106** and a return is made to the wait block **140**.

If in the decision **143** the frame is determined to be a control frame, then in a block **146** the control unit **102** generates and sends a response frame upstream to the master modem. The contents of the response frame depend on the nature of the received control frame and the status of the slave modem, but for example can include status information, an acknowledgement of the received data frame (based on the acknowledgement status flag), a request for retransmission of an incorrectly received frame (based on the retransmission status flag), and buffer fills of the buffers **104** and **106**. In a decision **147**, the control unit **102** then determines whether a data frame is to be sent upstream, i.e. whether the received downstream control frame included a retransmission request or a poll for an upstream data frame and such a data frame is available in the upstream transmission buffer **104**. If so, at a block **148** the control unit **102** sends the requested data frame from this buffer **104** upstream to the master modem. After the block **148**, or if no upstream frame is to be sent as determined in the decision **147**, a return is made to the wait block **140**.

Referring now to FIG. **13**, after the downstream transmitting sequence described above with reference to FIG. **12** the control unit **72** in the master modem **34** waits, as shown by a block **130**, for an upstream frame to be received or for the timer (set at block **122**) to time out. If an upstream frame is received, then in a decision **131** the control unit **72** determines from the field CHK whether the frame has been received properly and, if so, proceeds to a decision **132**. In the event that the timer times out in the block **130** or the frame is incorrectly received as determined in the decision **131**, then in a block **133** the control unit **72** updates a record of the communications status of the master modem with the slave modem. This status record contains various parameters of the communications such as those already discussed, for example the status of acknowledgements and retransmission requests, buffer fills, and operating parameters of the modems.

In the decision **132** the control unit determines, from the destination address of the received upstream frame and in accordance with its expectations based on the status of the communications, whether this is a response frame (i.e. the destination address is the address of the master modem) as expected first from the slave modem, or a data frame for which a poll or retransmission request has been sent to the slave modem as described above, or whether the frame does not have the expected form (e.g. it is a data frame when a response frame is expected). In the latter case the communications status is updated in the block **133**, and the control unit **72** proceeds in a manner dependent upon the updated status. For example, from the block **133** the control unit returns from the upstream receiving sequence of FIG. **13** to the downstream transmitting sequence of FIG. **12**, and can send a control frame requesting retransmission of an upstream frame for which there has been a timeout from the block **130**, a CRC error as determined in the decision **131**, or an unexpected frame as determined in the decision **132**.

On receipt of an expected response frame, in a block **134** the communications status is updated accordingly, and in dependence upon a decision **135** either a return is made to the block **130** for a data frame expected following the response frame (a data frame is expected if it has been requested from the slave modem and the response frame has not indicated that the upstream transmitting buffer **104** is empty; the timer for the block **130** can be reset as desired) or the receiving sequence ends if no subsequent data frame is expected. On receipt of an expected data frame as determined in the decision **132**, in a block **136** the control unit **72** sets a status flag for acknowledgement of the frame, and in a subsequent block **137** the received data frame is stored in the upstream receiving buffer **76** and the receiving sequence ends. As already described above, at the end of the upstream receiving sequence the control unit **72** of the master modem **34** returns to the start of the downstream transmitting sequence already described.

The collision avoidance protocol as described above provides for an approximate one-to-one ratio of downstream and upstream Ethernet frames, and gives priority to the master modem and the transmission of downstream frames. This is desirable because the modem arrangement has no control over the supply from the Network of Ethernet frames incoming to the buffer **74**, and it is desirable to avoid overflow of this buffer which would result in a loss of data frames. Such a data frame loss can be accommodated by the TCP/IP operating at Layers **3** and **4** of the OSI model, but this is preferably avoided.

The same principles apply for upstream Ethernet frames incoming to the buffer **104** from the TD **14**, but in this case overflow of the buffer **104** can be prevented by the Ethernet interface **100** of the slave modem **32**, under the control of the control unit **102** in the event that the buffer **104** is about to overflow, jamming the 10BASE-T connection on the wiring **46** by transmitting a dummy signal to it. As discussed in the introduction, jamming is a well-known process for ensuring that a collision detected at one device on a CSMA/CD LAN is also detected by all other devices on the LAN, but in this case the jamming is triggered differently, by the potential overflow of the buffer **104**. The jam or artificially created collision on the wiring **46** is detected by the TD **14** connected to this wiring, and the TD backs off for subsequent retransmission of the Ethernet frame in known manner. In this manner, a loss of upstream data frames due to overflow of the buffer **104** is avoided. The same situation can take place in the event that the wiring **46** is connected to the bridge **48** on a subscriber LAN as described with reference to FIG. **3**, but in this case either the bridge **48** must be a learning bridge to avoid passing to the slave modem **32** via the wiring **46** subscriber LAN frames not intended for upstream transmission, or such a learning function must be incorporated into the slave modem itself, otherwise jamming of all frames on the subscriber LAN will occur when the buffer **104** is about to overflow.

To reduce the possibility of buffer overflow, especially of the buffer **74**, the collision avoidance protocol described

above can provide dynamic variation of the ratio of the numbers of downstream and upstream frames, for example in dependence upon the fills of the buffers. The buffer fills are monitored as described above by the control unit **72**, either directly in the case of the master modem **34** or via status information in response frames from the slave modem **32**. If the fill of the buffer **74** is increasing, then the master modem can simply send a plurality of data frames downstream instead of each single data frame as described above with reference to FIG. **12**, before sending the control frame to poll the slave modem for an upstream data frame, thereby increasing the downstream to upstream data frame ratio. Conversely, if the buffer **74** is relatively empty and the buffer **104** is relatively full, the master modem can provide repeated polls for single upstream data frames without sending downstream data frames using the protocol exactly as described above, or more desirably the ECAP control frame poll can be arranged to indicate to the slave modem a number of data frames that it is requested to transmit upstream in response to particular polls, with the slave modem responding accordingly.

It can be appreciated from the description above that the collision avoidance protocol ensures that the modems **34** and **32** operate in a half-duplex manner for communications between them via the line **12**, with the total transmission capacity of the line being shared, preferably dynamically dependent upon buffer fills as described above, between the downstream and upstream directions of transmission. The protocol can be refined, from its basic form as described above, in various ways to maximize the efficiency with which the total transmission capacity is used. For example, such refinements can include provisions for sending multiple data frames successively in either direction as described above, concatenating or merging control and/or data frames sent in the same direction, and advancing the timing of downstream frame transmission from the master modem in view of the loop delay on the line **12** (which can be measured in known manner by the master modem) and the knowledge in the master modem control unit **72** of what upstream frames are expected from the slave modem.

This total transmission capacity on the line **12** can also be varied dynamically by the master modem **34** in dependence upon monitored operating conditions, as explained further below.

As described above, the modulation and demodulation functions in the master and slave modems are desirably implemented using DSPs. A clock rate of the DSPs can be changed to vary the signal bandwidth as shown by the two different spectra **62** and **64** in FIG. **6**. A high clock rate provides a corresponding large bandwidth, for example as shown by the spectrum **62** in FIG. **6**, providing a high symbol transmission rate on the line **12** between the modems **34** and **32**. However, this involves greater susceptibility to noise (a large noise bandwidth) and greater signal attenuation (which is dependent on frequency). Conversely, a lower clock rate provides a smaller bandwidth, for example as shown by the spectrum **64** in FIG. **6**, providing a lower symbol transmission rate on the line **12** with less susceptibility to noise and less signal attenuation. Considered generally, higher symbol rates on the line **12** produce greater total transmission capacity and greater error rates, resulting in frames having to be retransmitted.

As also described above, the control unit **72** in the master modem **34** determines from the check field CHK of each received upstream frame whether the frame has been received correctly, and can monitor a proportion of correct upstream frames received. The control unit **72** can similarly monitor a proportion of correct downstream frames received by the slave modem **32** from information similarly available in the control unit **102** of the slave modem and communicated to the control unit **72** via the response frames. From such ongoing monitoring, the control unit **72** can determine dynamically whether the clock rate in current use for the DSPs is appropriate or should desirably be increased to increase the total transmission capacity on the line **12** or decreased to decrease the proportion of frames received in error. This can be determined either independently or in common for the upstream and downstream directions of transmission.

For example, if the control unit determines that a high proportion, more than an upper threshold value of for example 95 to 99%, of frames are received correctly, then it can decide to increase the DSP clock rate and hence the total transmission capacity. To this end it generates a control frame which is sent from the master modem to the slave modem instructing the slave modem to adopt a new, higher, clock rate for future frames, the slave modem responds accordingly, and the master modem switches its own clock rate. Conversely, if the control unit determines that a low proportion, less than a lower threshold value of for example 50 to 75%, of frames are received correctly, then it can decide to decrease the DSP clock rate to reduce errors. To this end it generates a control frame which is sent from the master modem to the slave modem instructing the slave modem to adopt a new, lower, clock rate for future frames, the slave modem responds accordingly, and the master modem switches its own clock rate. It can be appreciated that the threshold levels can be determined to provide a desired hysteresis for changing the clock rate, and that they may be adaptively adjusted by the control unit **72** in dependence upon the results of previous changes in clock rate.

The total transmission capacity is determined not only by the symbol transmission rate on the line **12** but also by the number of bits per symbol, and hence by the modulation method that is used. As described above, the modem DSPs can provide any of a plurality of modulation methods, such as 16QAM, QPSK, and BPSK providing respectively **4** bits, 2 bits, and 1 bit per transmitted symbol. In a similar manner to that described above for dynamically varying the symbol transmission rate, the control unit **72** can also or instead dynamically vary the modulation method. A determination as to whether to change the symbol transmission rate and/or the modulation method can be made by the control unit **72** in dependence upon various parameters such as the current symbol transmission rate and modulation method, a history of these operating parameters, the error rate, and monitored characteristics of the line **12** such as delay, signal levels, and echo parameters.

In any event, the dynamic variations discussed above enable the control unit **72** in the master modem **34** to determine and use, at any particular time for any particular line **12** to which it is connected, a clock rate and modulation method to provide an optimal total transmission capacity on that line. It can be appreciated that this optimal capacity may well include a certain proportion of frames that are in error and must be retransmitted, and that this is accommodated by the collision avoidance protocol as already described above.

The total transmission capacity can vary over an extremely wide range. For example, for a short line **12** and under good conditions, the modulation method may be 16QAM and the clock rate 3 MHz to provide a total transmission capacity of the order of the 10BASE-T bit rate of 10 Mb/s. Conversely, for a long line **12** (it is observed here that the line **12** must be unloaded to permit communi-

cation of signals at frequencies above the voice-band) and in poor conditions (e.g. in the presence of noise and crosstalk) the modulation method may be BPSK and the clock rate may be reduced to for example 30 kHz, thereby providing a total transmission capacity of about 25 kb/s (at for example 0.85 bits per Hertz to allow for excess bandwidth of the modem filters). However, it is noted that even this total transmission capacity is commensurate with the maximum bit rates of dial-up modems currently used to provide Network connections via conventional two-wire telephone lines. In practice, the total transmission capacity provided will be between these extremes, and will generally be substantially more than can be provided by currently used dial-up modems or on ISDN telephone lines.

It is also noted that the master modem **34** can be arranged to fall back to known modem communications methods in the event that it does not receive any ECAP response frames from a slave modem, so that the same master modem can operate alternatively with slave modems as described above or with conventional modems.

In use of the network access arrangement and protocol as described above, the master and slave modems and the line **12** simply serve to communicate Ethernet frames in both directions transparently between the wiring **36** and **46**. Accordingly, the subscriber is provided with a Network connection without any dialling process, and hence without involving a telephone connection via the PSTN, in the same way (as seen by the Network and by the subscriber) as if the wiring **36** and **46** were directly interconnected. As described above, this Network connection is established in a manner that is dynamically variable to provide an optimum total transmission capacity, which can be shared in a dynamically variable and optimized ratio of upstream to downstream data frames, for any prevailing conditions such as the characteristics of the line **12** and noise and crosstalk levels. For short lines **12**, the total transmission capacity is comparable with the bit rate of 10BASE-T LANS, so that there is no inherent deterioration of performance for communication of Ethernet frames. In addition, it is observed that because the frames on the line **12** are communicated in burst mode, there is statistically less energy on the line than would be the case for continuous data transmission on the same line, so that crosstalk with other lines in the same cable is reduced. Furthermore, the same line **12** can simultaneously carry conventional telephone signals, so that provision of the network access arrangement to a telephone subscriber does not necessitate the provision of an additional or separate telephone line.

Thus the use of the network access arrangement from a TD **14** is substantially the same as if the TD **14** were connected directly via an Ethernet interface to the Ethernet switch **38**. The TD **14** runs conventional software which, for initial access to the Network, in known manner sends information packets in Ethernet frames upstream, these packets containing for example the Network address of the management device **42** as the destination address and the Network address of the TD **14** as the source address. The packets are routed via the Ethernet switch **38** in known manner to the device **42**, and the switch **38** stores the address of the TD **14** for subsequent direction of Ethernet frames addressed to this address to this TD. In known manner, the device **42** either recognizes the source address of the TD **14** and provides a welcome message, or does not recognize it and initiates a registration process, and communications continue in known manner except that they take place via the modems **34** and **32** and line **12** instead of via a direct connection as is known.

In the embodiments described in detail above and as illustrated in FIG. **3** the slave modem **32** is separate from the Ethernet interface **30** connected to the TD **14** and includes its own Ethernet interface and Network address. While this is convenient in the case that the slave modem is connected to a subscriber LAN via the wiring **46**, it can be superfluous or undesirable in the event that the slave modem **32** is connected to only a single TD **14**, especially if the slave modem **32** and Ethernet interface **30** are merged together into a combined unit that may be incorporated into the TD **14** as would be desirable for example for an entertainment device. Even in the case of a subscriber LAN, the bridge **48** can be considered as a terminal device in which the slave modem **32** could be incorporated.

It can be seen, therefore, that the manner in which the slave modem **32** is ultimately connected to the TD **14** is relatively arbitrary as far as this invention is concerned, it only being necessary that the information be converted or translated between the Ethernet frames to and from the buffers **104** and **106** of the slave modem and whatever form is required for the connection to the TD **14** (for example, a PCM/CIA interface of known form), and that a Network address identify the TD, translator, and/or slave modem. Desirably, the slave modem **32** and the Ethernet interface **30** are merged into a combined unit, which can have a form for example as illustrated in FIG. **15**.

Referring to FIG. **15**, the combined unit has a similar form and operation to the slave modem **32** as described above with reference to FIG. **8**, and the same reference numerals are used to denote similar parts, except that the Ethernet interface **100** and wiring **46** of the slave modem of FIG. **8**, as well as the Ethernet interface **30** of FIG. **3**, are replaced by a data translator **150**. The translator **150** has an interface **152** to the control unit **102** and buffers **104** and **106**, and an interface **154** to the TD **14**, which are arranged and operate in the same manner as the corresponding parts of the known Ethernet interfaces **100** and **30** discussed above. Between these interfaces **152** and **154**, the unit **150** includes a minimized subset of the known circuits and functions of the Ethernet interfaces **100** and **30** necessary to translate data between the TD interface **154** and the Ethernet frame buffers **104** and **106**, and to provide a single Network address. This avoids the disadvantage of needing two Network addresses for the slave modem **32** and the Ethernet interface **30** respectively as in the embodiments of the invention described above, but makes it necessary to distinguish between ECAP control frames for the control unit **102** and ECAP data frames enveloping Ethernet frames containing data for the TD **14**.

Where the control frames and data frames are separate ECAP frames, this distinction can conveniently be provided by using the L/T field of the Ethernet frame. For an ECAP control frame, the L/T field can contain a pre-assigned (and otherwise unused) type having a value greater than the maximum value of 1500 for an Ethernet frame, which is recognized by the control unit **102** so that the control frame is not forwarded to the translator **150**. Alternatively, or in addition, as described above ECAP control information can be appended to Ethernet frames, for example in the overhead field O/H or between the FCS field of the enveloped Ethernet frame and the check field CHK of the ECAP frame. In either case the control information can be of a fixed size or it can include its own length field to indicate its size. The L/T field of the enveloped Ethernet frame is not changed, to avoid any risk of corrupting the Ethernet frame.

Although particular embodiments of the invention and various modifications have been described in detail, it

should be appreciated that numerous other modifications, variations, and adaptations may be made without departing from the scope of the invention as defined in the claims.

What is claimed is:

1. A method of providing communications with a CSMA/CD (Carrier Sense Multiple Access with Collision Detection) network via a bidirectional communications path, comprising the steps of:

at a first end of the communications path, providing a CSMA/CD interface to the network, buffering information packets received from the network via the interface in a first buffer, supplying information packets from the first buffer to the communications path, and supplying control information to the communications path;

at a second end of the communications path, buffering information packets received via the communications path in a second buffer, receiving the control information from the communications path, buffering information packets to be supplied via the communications path to the network in a third buffer, and supplying information packets from the third buffer to the communications path in dependence upon the control information; and

at the first end of the communications path, supplying information packets received via the communications path to a fourth buffer, and supplying the information packets from the fourth buffer to the network via the interface;

wherein the control information and the dependence on the control information for supplying information packets from the third buffer to the communications path are arranged to avoid collisions on the communications path between information packets communicated from the first buffer to the second buffer and information packets communicated from the third buffer to the fourth buffer.

2. A method as claimed in claim **1** and further comprising the steps of monitoring fills of at least some of the buffers, and varying a ratio of information packets communicated from the first buffer to the second buffer to information packets communicated from the third buffer to the fourth buffer in dependence upon the monitored fills.

3. A method as claimed in claim **1** wherein the steps of supplying information packets from the first buffer to the communications path and supplying information packets from the third buffer to the communications path comprise enveloping information packets in information frames, the information frames also comprising error check fields for error checking of at least the enveloped information packets.

4. A method as claimed in claim **3** wherein the step of supplying control information to the communications path comprises including control information in at least some of the information frames.

5. A method as claimed in claim **3** wherein the step of supplying control information to the communications path comprises communicating further frames, each further frame comprising control information and an error check field for error checking of at least the control information.

6. A method as claimed in claim **1** wherein each information packet communicated via the communications path comprises at least address, length, and data fields of an Ethernet frame communicated via the CSMA/CD interface.

7. A method as claimed in claim **6** wherein each information packet communicated via the communications path further comprises a frame check sequence of the respective Ethernet frame communicated via the CSMA/CD interface.

8. A method as claimed in claim **7** wherein each information packet communicated via the communications path further comprises a preamble and start frame delimiter of an Ethernet frame.

9. A method as claimed in claim **1** wherein the information packets are communicated via the communications path as modulated signals between modems at the first and second ends of the communications path.

10. A method as claimed in claim **9** and further comprising the steps of monitoring errors in communicating information packets via the communications path and varying a signal bandwidth of the modems in dependence upon the monitored errors.

11. A method as claimed in claim **9** and further comprising the steps of monitoring errors in communicating information packets via the communications path and varying a modulation method of the modems in dependence upon the monitored errors.

12. A method as claimed in claim **9** and further comprising the step of multiplexing the modem at the first end of the communications path for communicating information packets with a plurality of modems at the second ends of a plurality of respective communication paths.

13. A method as claimed in claim **9** wherein the communications path comprises a two-wire telephone subscriber line and the modems communicate said information packets via the line at frequencies greater than telephone signal frequencies, the method further comprising the steps of:

communicating telephone signals via the line; and

at each end of the line, combining telephone signals and information packets to be communicated via the line, and separating telephone signals and information packets communicated via the line, using a diplexer.

14. A method as claimed in claim **13** and further comprising the step of multiplexing the modem at the first end of the communications path for communicating information packets with a plurality of modems at the second ends of a plurality of respective telephone subscriber lines.

15. A method as claimed in claim **1** and further comprising the steps of providing a second CSMA/CD interface to a CSMA/CD path at the second end of the communications path and communicating information packets between the second and third buffers and the CSMA/CD path via the second CSMA/CD interface.

16. A method as claimed in claim **15** and further comprising the step of jamming the CSMA/CD path from the second CSMA/CD interface in response to filling of the third buffer.

17. A method as claimed in claim **2** wherein the information packets are communicated via the communications path as modulated signals between modems at the first and second ends of the communications path.

18. A method as claimed in claim **17** and further comprising the steps of monitoring errors in communicating information packets via the communications path and varying a signal bandwidth of the modems in dependence upon the monitored errors.

19. A method as claimed in claim **17** and further comprising the steps of monitoring errors in communicating information packets via the communications path and varying a modulation method of the modems in dependence upon the monitored errors.

20. A method as claimed in claim **17** and further comprising the step of multiplexing the modem at the first end of the communications path for communicating information packets with a plurality of modems at the second ends of a plurality of respective communication paths.

21. A method as claimed in claim **17** wherein the communications path comprises a two-wire telephone subscriber line and the modems communicate said information packets via the line at frequencies greater than telephone signal frequencies, the method further comprising the steps of:

communicating telephone signals via the line; and

at each end of the line, combining telephone signals and information packets to be communicated via the line, and separating telephone signals and information packets communicated via the line, using a diplexer.

22. A method as claimed in claim **21** and further comprising the step of multiplexing the modem at the first end of the communications path for communicating information packets with a plurality of modems at the second ends of a plurality of respective telephone subscriber lines.

23. A method as claimed in claim **18** wherein the communications path comprises a two-wire telephone subscriber line and the modems communicate said information packets via the line at frequencies greater than telephone signal frequencies, the method further comprising the steps of:

communicating telephone signals via the line; and

at each end of the line, combining telephone signals and information packets to be communicated via the line, and separating telephone signals and information packets communicated via the line, using a diplexer.

24. A method as claimed in claim **23** and further comprising the step of multiplexing the modem at the first end of the communications path for communicating information packets with a plurality of modems at the second ends of a plurality of respective telephone subscriber lines.

25. A method as claimed in claim **19** wherein the communications path comprises a two-wire telephone subscriber line and the modems communicate said information packets via the line at frequencies greater than telephone signal frequencies, the method further comprising the steps of:

communicating telephone signals via the line; and

at each end of the line, combining telephone signals and information packets to be communicated via the line, and separating telephone signals and information packets communicated via the line, using a diplexer.

26. A method as claimed in claim **25** and further comprising the step of multiplexing the modem at the first end of the communications path for communicating information packets with a plurality of modems at the second ends of a plurality of respective telephone subscriber lines.

27. A method as claimed in claim **2** and further comprising the steps of providing a second CSMA/CD interface to a CSMA/CD path at the second end of the communications path and communicating information packets between the second and third buffers and the CSMA/CD path via the second CSMA/CD interface.

28. A method as claimed in claim **3** and further comprising the steps of providing a second CSMA/CD interface to a CSMA/CD path at the second end of the communications path and communicating information packets between the second and third buffers and the CSMA/CD path via the second CSMA/CD interface.

29. A method as claimed in claim **4** and further comprising the steps of providing a second CSMA/CD interface to a CSMA/CD path at the second end of the communications path and communicating information packets between the second and third buffers and the CSMA/CD path via the second CSMA/CD interface.

30. A method as claimed in claim **5** and further comprising the steps of providing a second CSMA/CD interface to a CSMA/CD path at the second end of the communications path and communicating information packets between the second and third buffers and the CSMA/CD path via the second CSMA/CD interface.

31. A method as claimed in claim **6** and further comprising the steps of providing a second CSMA/CD interface to a CSMA/CD path at the second end of the communications path and communicating information packets between the second and third buffers and the CSMA/CD path via the second CSMA/CD interface.

32. A method as claimed in claim **7** and further comprising the steps of providing a second CSMA/CD interface to a CSMA/CD path at the second end of the communications path and communicating information packets between the second and third buffers and the CSMA/CD path via the second CSMA/CD interface.

33. A method as claimed in claim **8** and further comprising the steps of providing a second CSMA/CD interface to a CSMA/CD path at the second end of the communications path and communicating information packets between the second and third buffers and the CSMA/CD path via the second CSMA/CD interface.

34. A method as claimed in claim **9** and further comprising the steps of providing a second CSMA/CD interface to a CSMA/CD path at the second end of the communications path and communicating information packets between the second and third buffers and the CSMA/CD path via the second CSMA/CD interface.

35. A method as claimed in claim **10** and further comprising the steps of providing a second CSMA/CD interface to a CSMA/CD path at the second end of the communications path and communicating information packets between the second and third buffers and the CSMA/CD path via the second CSMA/CD interface.

36. A method as claimed in claim **11** and further comprising the steps of providing a second CSMA/CD interface to a CSMA/CD path at the second end of the communications path and communicating information packets between the second and third buffers and the CSMA/CD path via the second CSMA/CD interface.

37. A method as claimed in claim **12** and further comprising the steps of providing a second CSMA/CD interface to a CSMA/CD path at the second end of the communications path and communicating information packets between the second and third buffers and the CSMA/CD path via the second CSMA/CD interface.

38. A method as claimed in claim **13** and further comprising the steps of providing a second CSMA/CD interface to a CSMA/CD path at the second end of the communications path and communicating information packets between the second and third buffers and the CSMA/CD path via the second CSMA/CD interface.

39. A method as claimed in claim **14** and further comprising the steps of providing a second CSMA/CD interface to a CSMA/CD path at the second end of the communications path and communicating information packets between the second and third buffers and the CSMA/CD path via the second CSMA/CD interface.

40. A method as claimed in claim **17** and further comprising the steps of providing a second CSMA/CD interface to a CSMA/CD path at the second end of the communications path and communicating information packets between the second and third buffers and the CSMA/CD path via the second CSMA/CD interface.

41. A method as claimed in claim **21** and further comprising the steps of providing a second CSMA/CD interface to a CSMA/CD path at the second end of the communications path and communicating information packets between

the second and third buffers and the CSMA/CD path via the second CSMA/CD interface.

42. A method of coupling a terminal device to a CSMA/CD (Carrier Sense Multiple Access with Collision Detection) network via a two-wire telephone subscriber line, comprising the steps of:

coupling a first end of the line to the network via a first modem including a CSMA/CD interface to the network;

coupling a second end of the line to the terminal device via a second modem including an interface to the terminal device;

communicating information packets downstream from the network to the terminal device via the CSMA/CD interface, first modem, line, second modem, and terminal device interface;

communicating control information downstream from the first modem to the second modem; and

communicating information packets upstream from the terminal device to the network via the terminal device interface, second modem, line, first modem, and CSMA/CD interface under control of the control information at times to avoid interference with the information packets and control information communicated downstream.

43. A method as claimed in claim **42** wherein the modems communicate via the line at frequencies greater than telephone signal frequencies and the method further comprises the step of frequency diplexing telephone signals and modem communications on the line.

44. A method as claimed in claim **42** and further comprising the step of multiplexing the first modem for communications with a plurality of second modems via respective telephone subscriber lines.

45. A method as claimed in claim **42** and further comprising the steps of monitoring errors in communicating information packets between the first and second modems and varying a signal bandwidth of the modems in dependence upon monitored errors.

46. A method as claimed in claim **42** and further comprising the steps of monitoring errors in communicating information packets between the first and second modems and varying a modulation method of the modems in dependence upon monitored errors.

47. A method as claimed in claim **42** and further comprising the steps of buffering information packets in information packet buffers at the first and second modems, monitoring fills of the information packet buffers, and varying a ratio of information packets communicated downstream to information packets communicated upstream in dependence upon the monitored fills.

48. A network access arrangement for providing communications with a CSMA/CD (Carrier Sense Multiple Access with Collision Detection) path via a communications path, comprising:

a first unit for coupling a first end of the communications path to the CSMA/CD path, the first unit comprising a CSMA/CD interface for connection to the CSMA/CD path, a buffer for buffering information packets supplied from the CSMA/CD path via the CSMA/CD interface for supply to the communications path, a buffer for buffering information packets received from the communications path for supply to the CSMA/CD path via the CSMA/CD interface, and a control unit; and

a second unit for connection to a second end of the communications path, the second unit comprising a buffer for buffering information packets received via the communications path, a buffer for buffering information packets to be supplied to the communications path, and a control unit;

wherein the control units of the first and second units are arranged to exchange control information via the communications path for communicating information packets bidirectionally via the communications path between the buffers of the first and second units in a half duplex manner.

49. A network access arrangement as claimed in claim **48** wherein the first and second units comprise modems for communicating the information packets and control information as modulated signals via the communications path.

50. A network access arrangement as claimed in claim **49** wherein the modems of the first and second units are arranged to produce the modulated signals at frequencies greater than telephone signal frequencies, and each of the first and second units includes a frequency diplexer via which the units are coupled to the communications path, the diplexers having further connections for telephone equipment for simultaneous communications of telephone signals via the communications path.

51. A network access arrangement as claimed in claim **48** wherein the first unit comprises respective buffers for a plurality of communications paths and further comprises a multiplexer and demultiplexer for multiplexed connections of the CSMA/CD interface via respective buffers to respective communications paths.

52. A network access arrangement as claimed in claim **48** wherein the second unit comprises a CSMA/CD interface for coupling information packets between the buffers of the second unit and a CSMA/CD path at the second end of the communications path.

53. A network access arrangement as claimed in claim **49** wherein the second unit comprises a CSMA/CD interface for coupling information packets between the buffers of the second unit and a CSMA/CD path at the second end of the communications path.

54. A network access arrangement as claimed in claim **50** wherein the first unit comprises respective buffers for a plurality of communications paths and further comprises a multiplexer and demultiplexer for multiplexed connections of the CSMA/CD interface via respective buffers to respective communications paths.

55. A network access arrangement as claimed in claim **54** wherein the second unit comprises a CSMA/CD interface for coupling information packets between the buffers of the second unit and a CSMA/CD path at the second end of the communications path.

56. A modem for communicating information packets of Ethernet frames via a two-wire line, comprising:

a control unit;

an interface for supplying and receiving information packets of Ethernet frames;

a first buffer for receiving and buffering information packets from the interface;

a modulator responsive to the control unit for supplying modulated signals comprising information packets from the first buffer to a two-wire line;

a demodulator for demodulating modulated signals received via the two-wire line to produce demodulated signals; and

a second buffer for receiving and buffering information packets contained in the demodulated signals for supply to the interface;

wherein the control unit is arranged to produce or respond to control information in the modulated signals on the two-wire line to control the modulator to supply modulated signals to the two-wire line only at times when modulated signals are not being received via the two-wire line.

57. A modem as claimed in claim **56** wherein the interface comprises a CSMA/CD (Carrier Sense Multiple Access with Collision Detection) interface to a CSMA/CD path.

58. A modem as claimed in claim **56** wherein the modulator supplies, and the demodulator demodulates, said modulated signals at frequencies greater than telephone signal frequencies, and further comprising a frequency diplexer for coupling the modulated signals to and from the two-wire line and having a two-wire connection for telephone equipment for simultaneously coupling telephone signals to and from the two-wire line.

59. A modem as claimed in claim **56** and further comprising a high pass filter for coupling the two-wire line to the demodulator, the high pass filter providing a matched termination for the two-wire line.

60. A modem as claimed in claim **59** and further comprising a current generator for coupling the modulator to the two-wire line.

61. A modem as claimed in claim **56** wherein the control unit is arranged to produce said control information for said modulated signals on a plurality of two-wire lines, the modem comprising respective first and second buffers for buffering information packets in respect of each of the plurality of lines, the modem further comprising a multiplexer controlled by the control unit to couple any of the plurality of two-wire lines to the demodulator, and a demultiplexer controlled by the control unit to couple the modulator to any of the plurality of two-wire lines.

62. A modem as claimed in claim **61** and including a store controlled by the control unit for storing and supplying to the modulator or demodulator information relating to modulation or demodulation, respectively, characteristics for each of the plurality of two-wire lines.

63. A modem as claimed in claim **61** wherein the modulator supplies, and the demodulator demodulates, said modulated signals at frequencies greater than telephone signal frequencies, and further comprising a frequency diplexer for coupling the modulated signals to and from the two-wire line and having a two-wire connection for telephone equipment for simultaneously coupling telephone signals to and from the two-wire line.

64. A modem as claimed in claim **63** wherein the interface comprises a CSMA/CD (Carrier Sense Multiple Access with Collision Detection) interface to a CSMA/CD path.

65. A modem as claimed in claim **61** wherein the interface comprises a CSMA/CD (Carrier Sense Multiple Access with Collision Detection) interface to a CSMA/CD path.

66. A method as claimed in claim **47** wherein the modems communicate via the line at frequencies greater than telephone signal frequencies and the method further comprises the step of frequency diplexing telephone signals and modem communications on the line.

67. A method as claimed in claim **47** and further comprising the step of multiplexing the first modem for communications with a plurality of second modems.

68. A method as claimed in claim **47** and further comprising the steps of monitoring errors in communicating information packets between the first and second modems and varying a signal bandwidth of the modems in dependence upon monitored errors.

69. A method as claimed in claim **47** and further comprising the steps of monitoring errors in communicating information packets between the first and second modems and varying a modulation method of the modems in dependence upon monitored errors.

70. A modem as claimed in claim **58** wherein the interface comprises a CSMA/CD (Carrier Sense Multiple Access with Collision Detection) interface to a CSMA/CD path.

71. A modem for coupling a device to a two-wire line for providing packetized communications for the device via the line, the modem comprising:

an interface for coupling to the device;

a controller;

a demodulator for receiving, from the line and for demodulating downstream modulated signals comprising control signals for the controller and information packets for supply via the interface to the device;

a buffer for buffering information packets received from the device via the interface; and

a modulator for receiving information packets from the buffer for producing and supplying upstream modulated signals to the line, the controller being responsive to the demodulated control signals for controlling the modulator so that the upstream modulated signals are timed to avoid interference with the downstream modulated signals.

* * * * *

ADDENDUM D

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(12) **United States Patent**
Terry et al.

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(45) **Date of Patent: *Dec. 4, 2001**

(54) **INFORMATION NETWORK ACCESS APPARATUS AND METHODS FOR COMMUNICATING INFORMATION PACKETS VIA TELEPHONE LINES**

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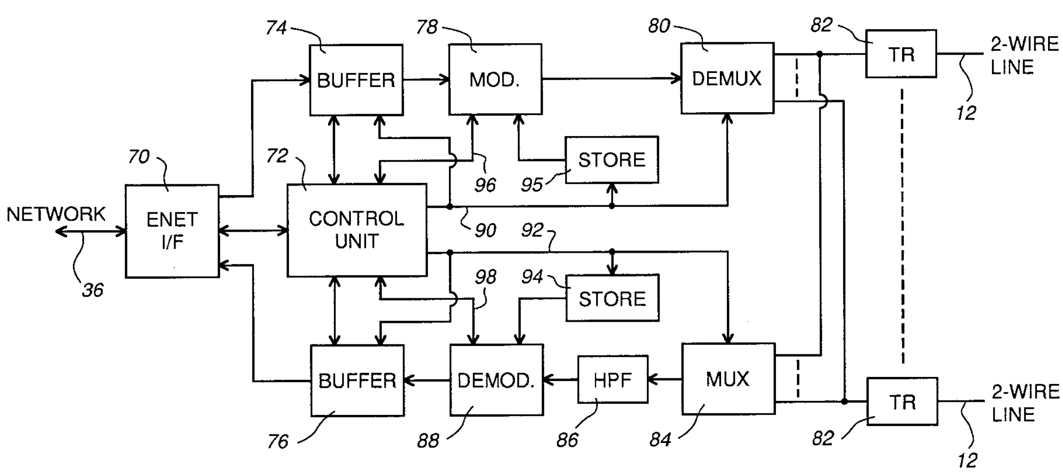
5,541,967	7/1996	Gluska et al.	375/364
5,636,037	6/1997	Saitoh	358/442
5,657,358	8/1997	Panech et al.	375/316
5,668,857	9/1997	Michale et al.	379/93.07
5,781,617	7/1998	Michale et al.	379/93.14

Primary Examiner—Ajit Patel
(74) *Attorney, Agent, or Firm*—Hunton & Williams

(57) **ABSTRACT**

Access to a CSMA/CD (Carrier Sense Multiple Access with Collision Detection) network is provided via a telephone line by providing a master modem at the head end and a slave modem at the subscriber end of the line. The master modem provides a CSMA/CD interface to the network and controls half duplex communications with the slave modem via the line to avoid collisions of information packets on the line. The information packets are enveloped in frames on the line with error checking information; control information between the modems is contained in the same and/or in separate frames. The modulation method and signal bandwidth can be varied depending on errors to provide optimum communications capacity via any particular line, and a ratio of upstream to downstream information packets can be varied depending on buffer fills at the modems. The master modem can be multiplexed for multiple lines. The modulated signal frequencies are above telephone signal frequencies so that each line can be frequency diplexed for simultaneous telephone communications.

9 Claims, 8 Drawing Sheets



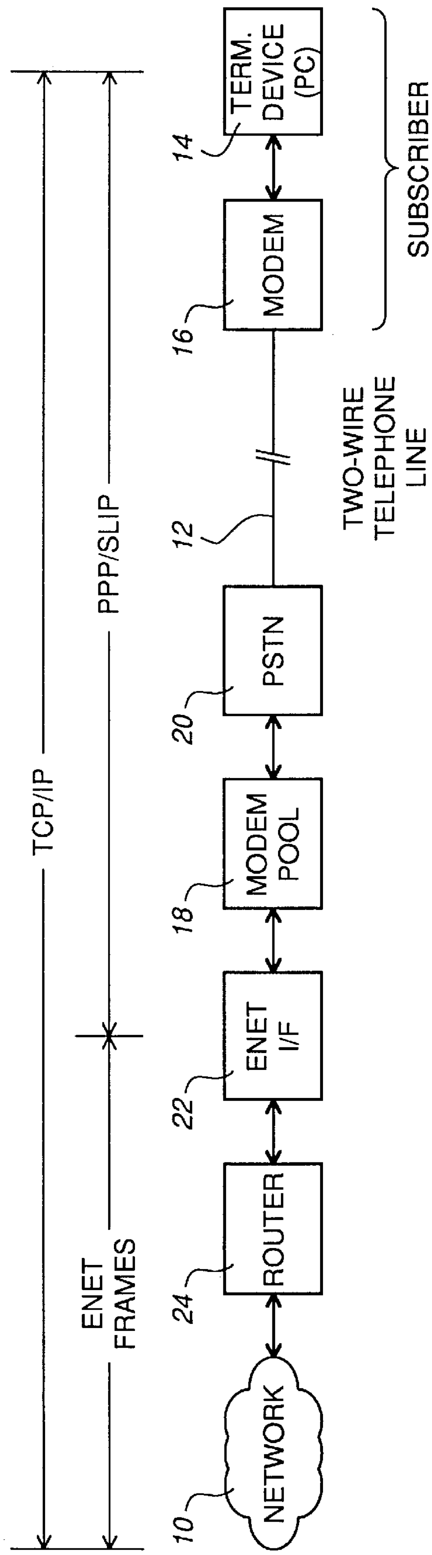


Fig. 1 PRIOR ART

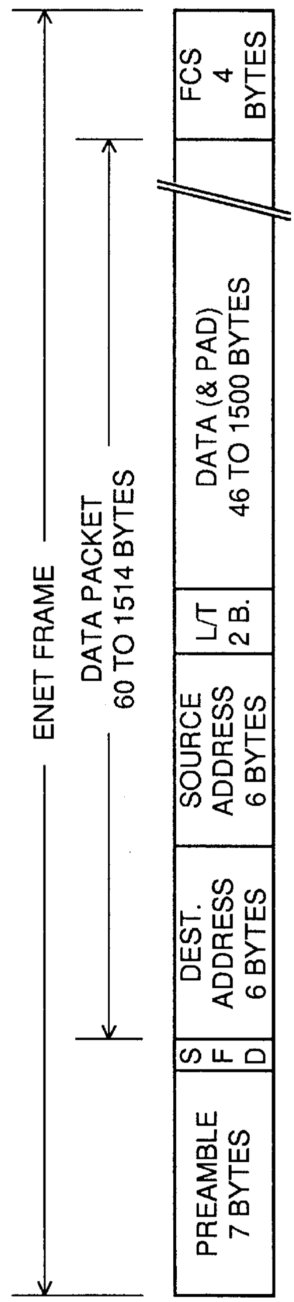


Fig. 2 PRIOR ART

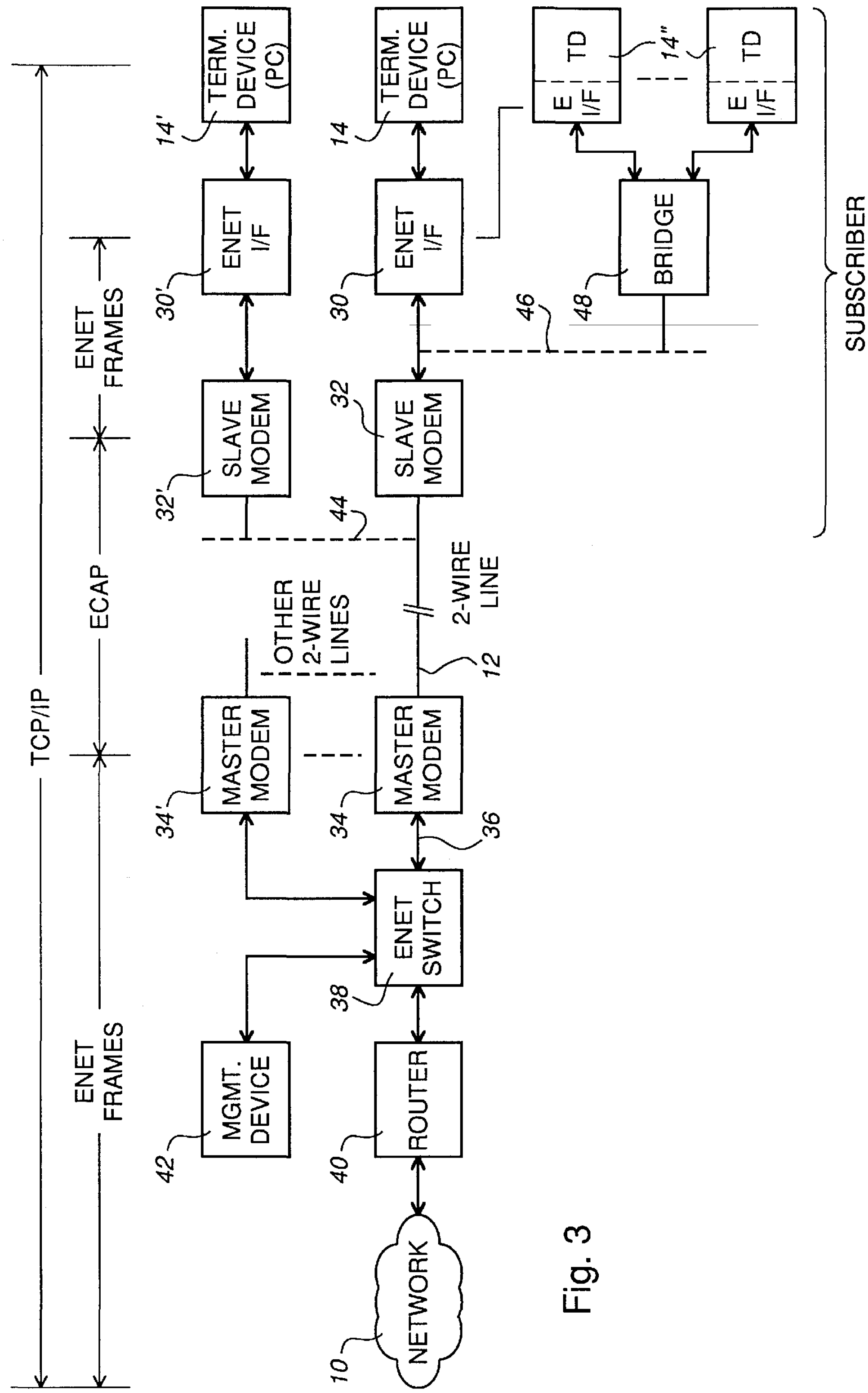

TERM. DEVICE (PC)
14'
TERM. DEVICE (PC)
14
TD
E I/F
14"
TD
E I/F
ENET I/F
30'
ENET I/F
30
BRIDGE
48
46
SUBSCRIBER
SLAVE MODEM
32'
SLAVE MODEM
32
44
2-WIRE LINE
OTHER 2-WIRE LINES
12
MASTER MODEM
34'
MASTER MODEM
34
36
ENET SWITCH
38
MGMT. DEVICE
42
ROUTER
40
NETWORK
10
TCP/IP
ENET FRAMES
ECAP
ENET FRAMES

Fig. 3

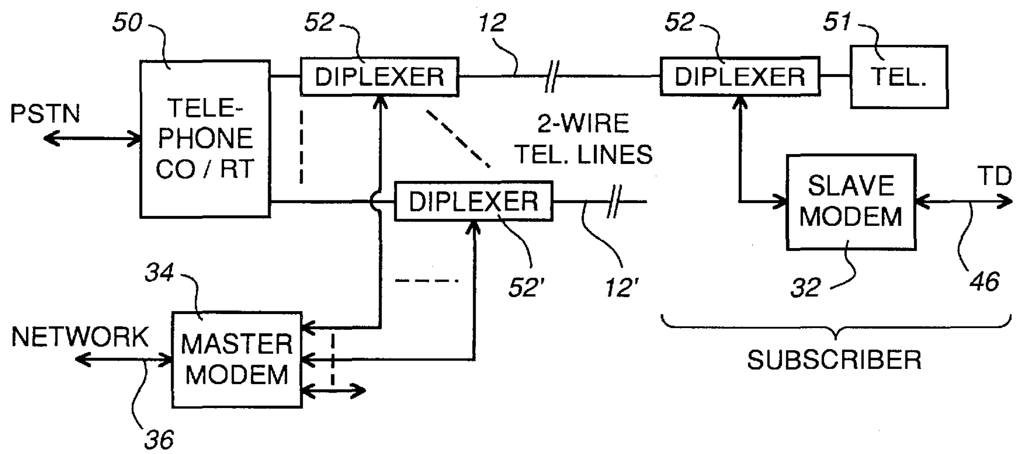


Fig. 4

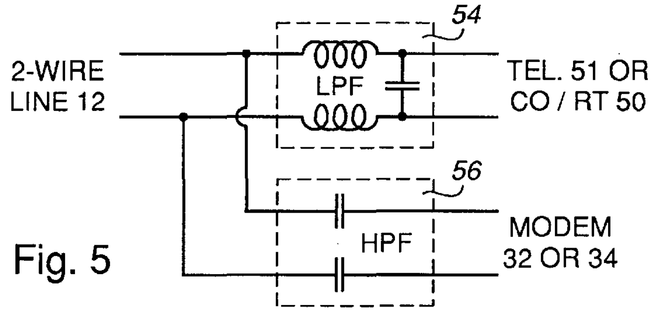


Fig. 5

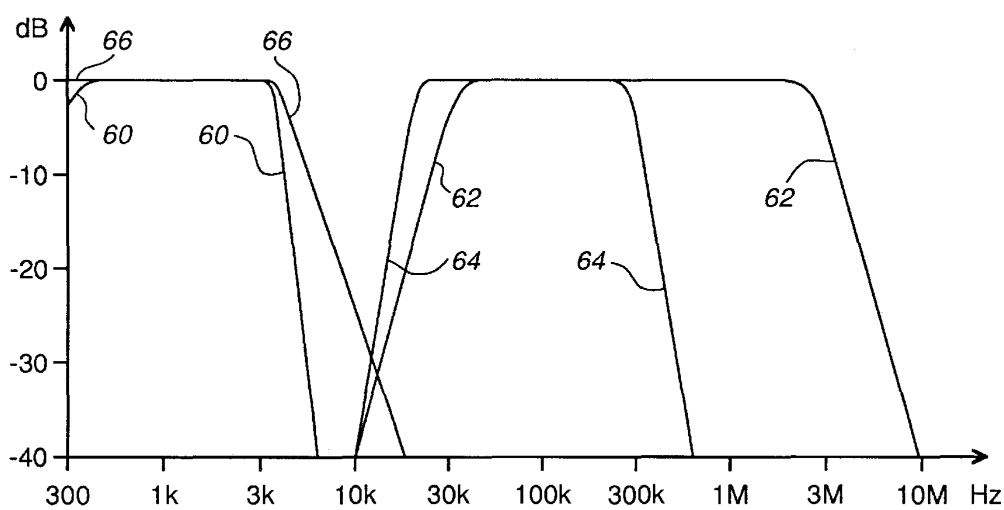


Fig. 6

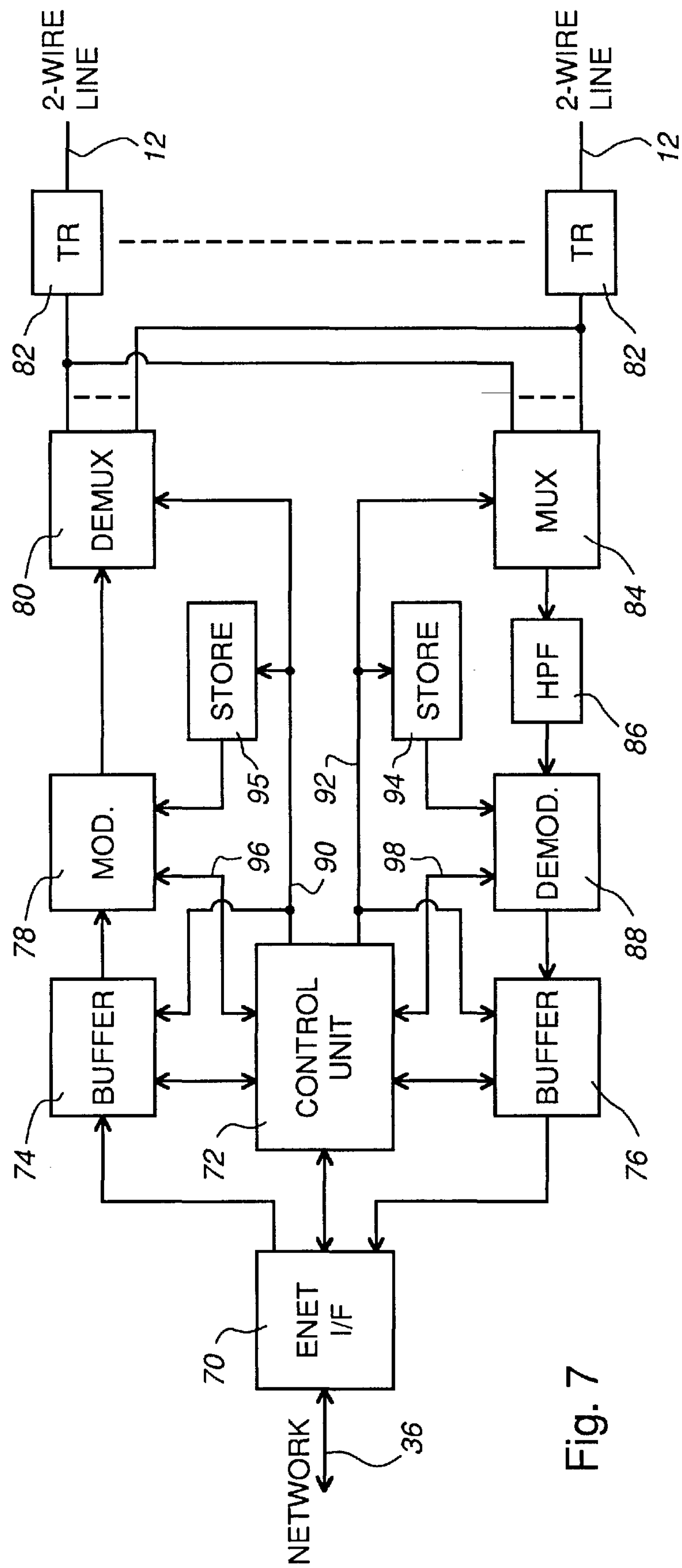

2-WIRE LINE
12
TR
82
2-WIRE LINE
12
TR
82
DEMUX
80
MUX
84
STORE
95
STORE
94
HPF
86
92
MOD.
78
96
90
98
DEMOD.
88
BUFFER
74
CONTROL UNIT
72
BUFFER
76
ENET I/F
70
NETWORK
36

Fig. 7

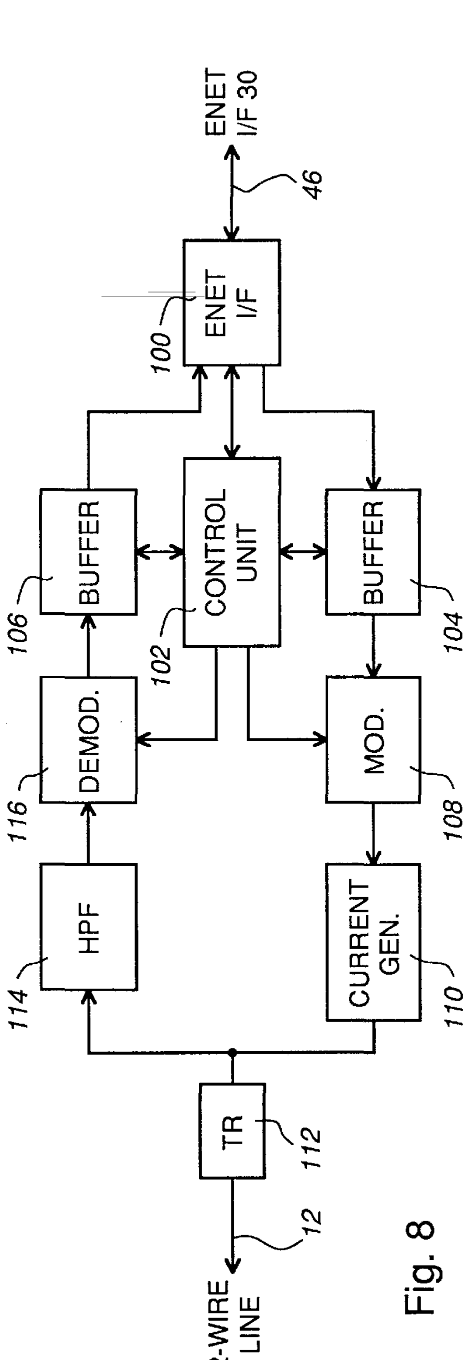

ENET I/F 30
46
ENET I/F
100
BUFFER
106
CONTROL UNIT
102
BUFFER
104
DEMOD.
116
MOD.
108
HPF
114
CURRENT GEN.
110
TR
112
12
2-WIRE LINE

Fig. 8

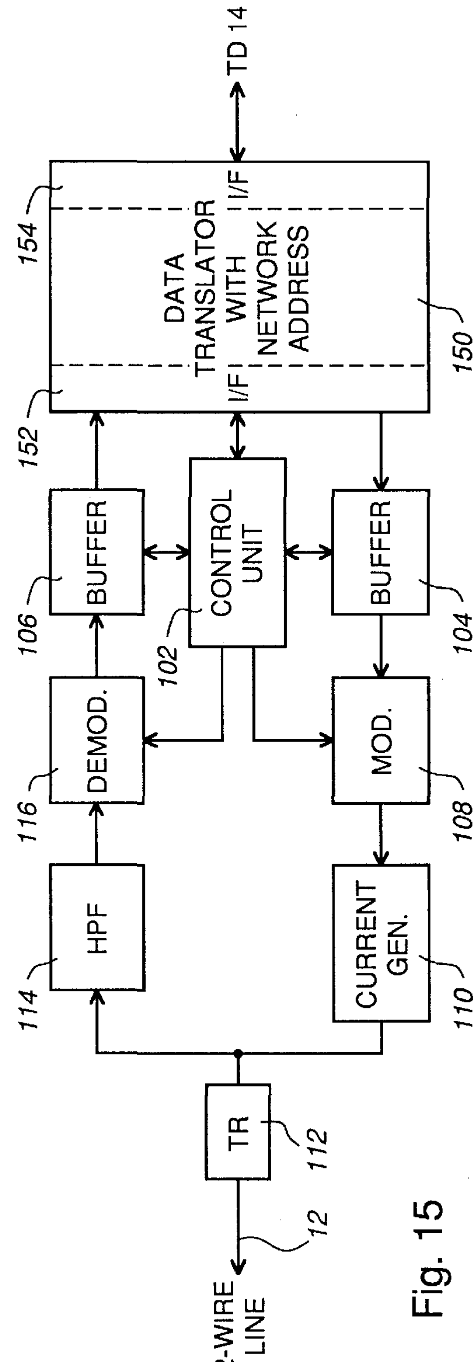

TD 14
154
I/F
DATA TRANSLATOR WITH NETWORK ADDRESS
I/F
152
150
BUFFER
106
CONTROL UNIT
102
BUFFER
104
DEMOD.
116
MOD.
108
HPF
114
CURRENT GEN.
110
TR
112
12
2-WIRE LINE

Fig. 15

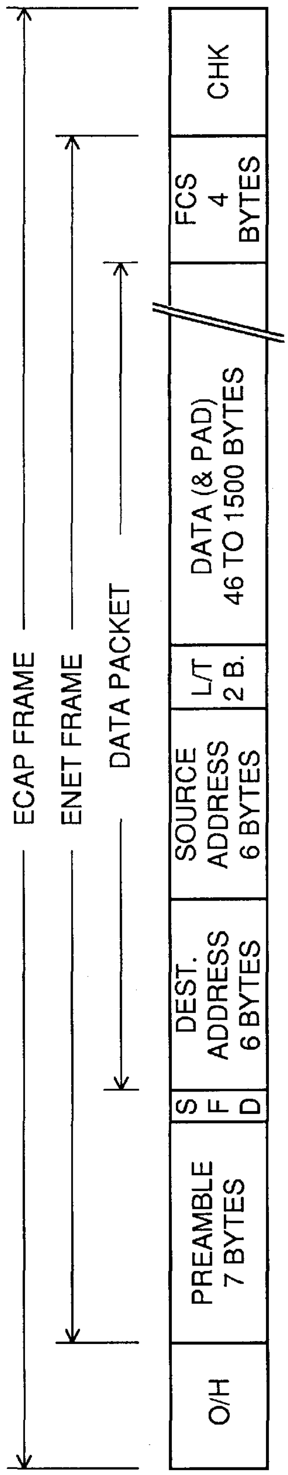


Fig. 9

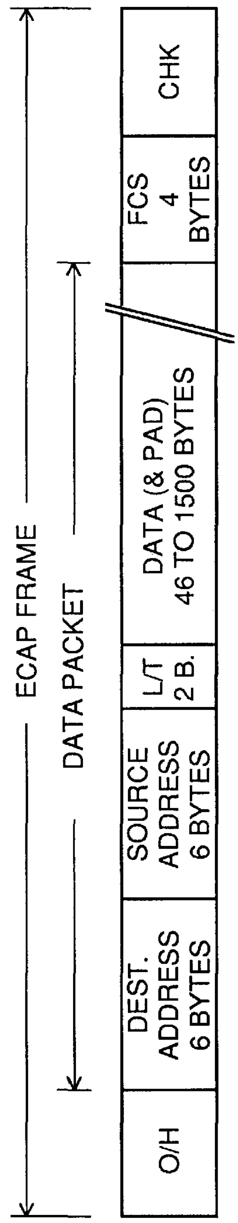


Fig. 10

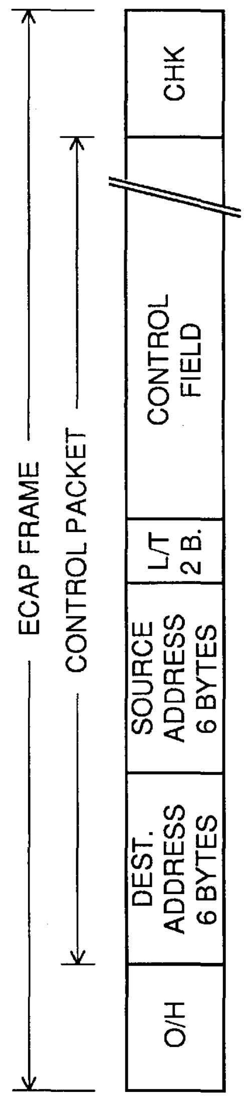
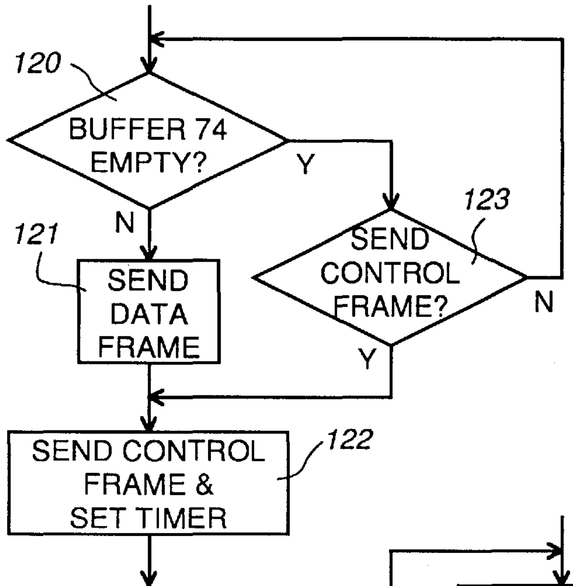
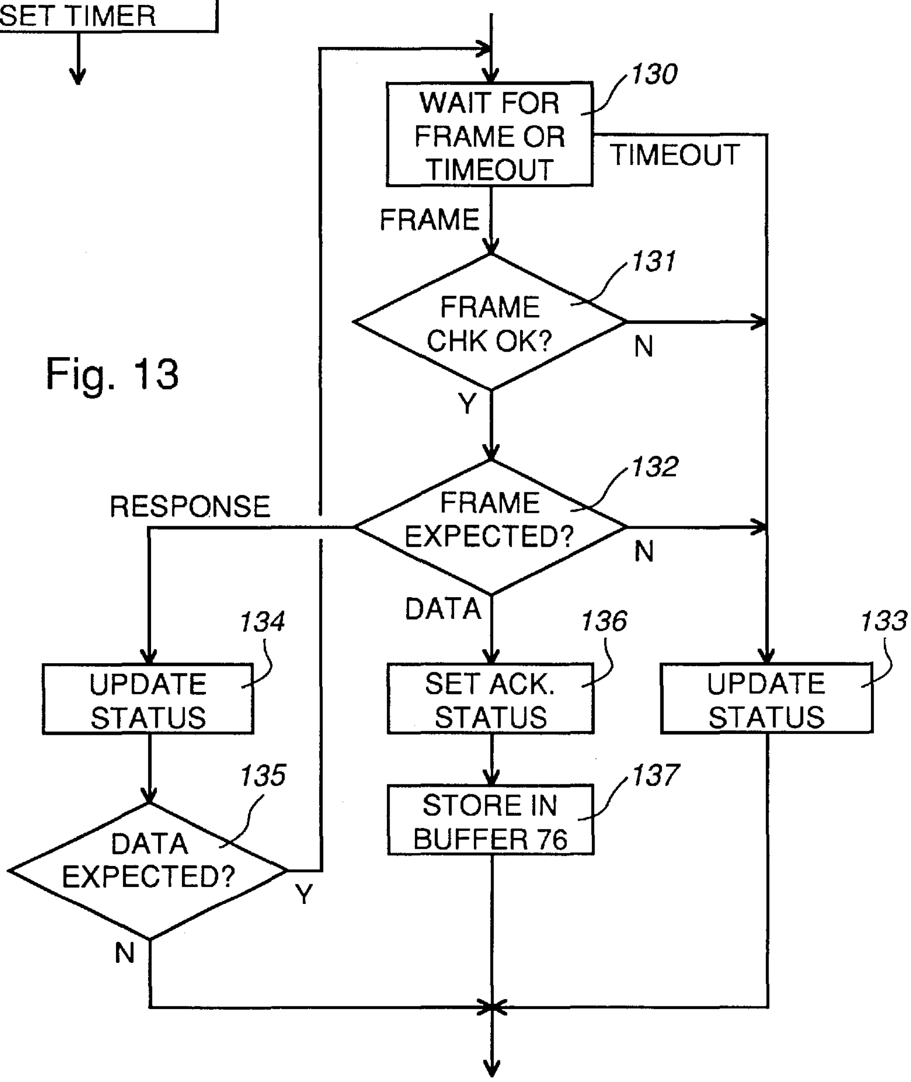


Fig. 11



120
BUFFER 74 EMPTY?
Y
N
121
SEND DATA FRAME
123
SEND CONTROL FRAME?
N
Y
SEND CONTROL FRAME & SET TIMER
122

Fig. 12



WAIT FOR FRAME OR TIMEOUT
130
TIMEOUT
FRAME
131
FRAME CHK OK?
N
Y
132
FRAME EXPECTED?
RESPONSE
N
DATA
134
UPDATE STATUS
136
SET ACK. STATUS
133
UPDATE STATUS
135
DATA EXPECTED?
Y
N
137
STORE IN BUFFER 76

Fig. 13

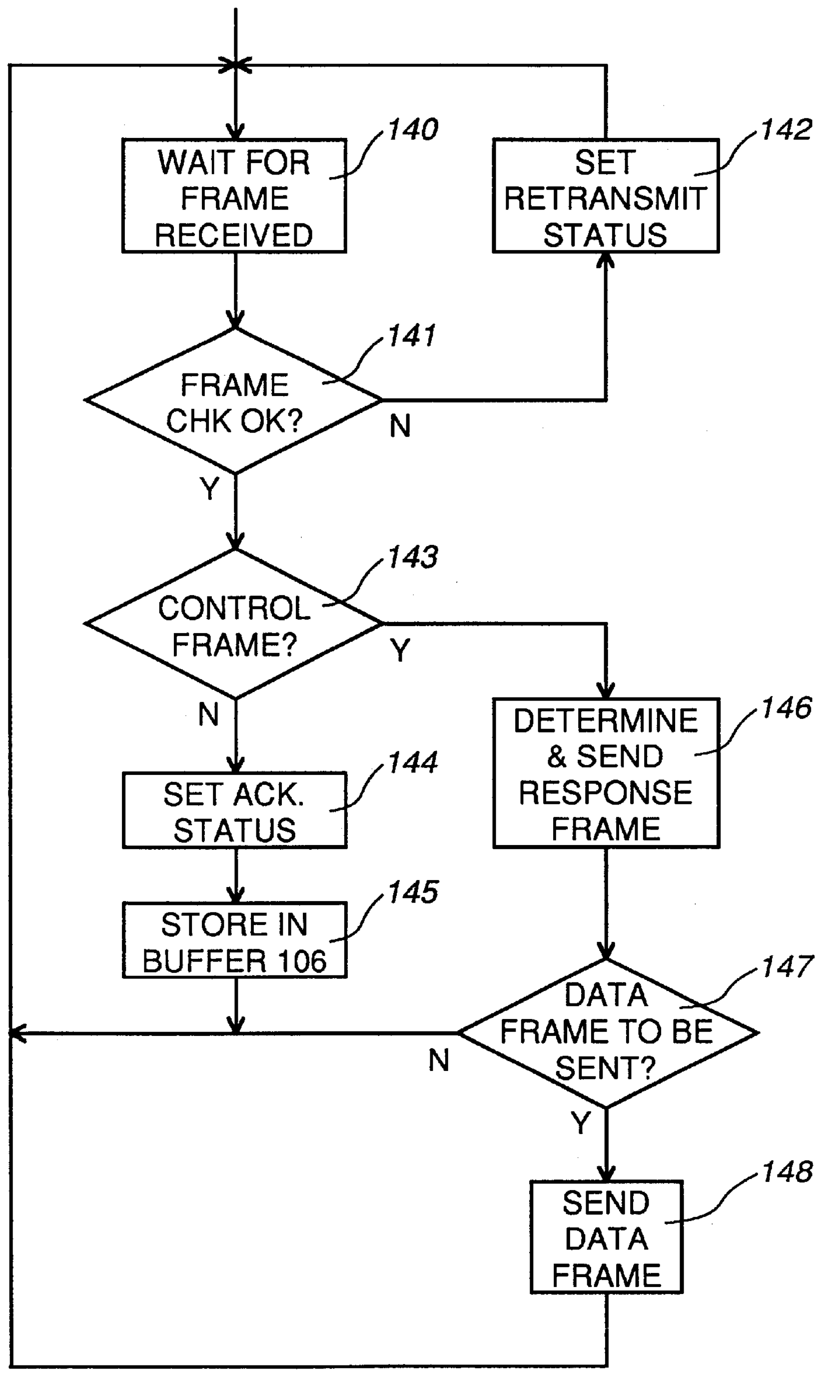

WAIT FOR FRAME RECEIVED
140
SET RETRANSMIT STATUS
142
FRAME CHK OK?
141
N
Y
CONTROL FRAME?
143
Y
N
DETERMINE & SEND RESPONSE FRAME
146
SET ACK. STATUS
144
STORE IN BUFFER 106
145
DATA FRAME TO BE SENT?
147
N
Y
SEND DATA FRAME
148

Fig. 14

INFORMATION NETWORK ACCESS APPARATUS AND METHODS FOR COMMUNICATING INFORMATION PACKETS VIA TELEPHONE LINES

This application is a continuation of Application No. 08/640,705 filed May 1, 1996, now U.S. Pat. No, 5,912,895.

This is a continuation of U.S. patent application Ser. No. 08/640,705 filed May 1, 1996 in the names of J. B. Terry et al. entitled "Information Network Access Apparatus And Methods For Communicating Information Packets Via Telephone Lines", pending, the entire disclosure of which is hereby incorporated herein by reference.

This invention relates to information network access, and is particularly concerned with apparatus and methods for communicating information packets, generally referred to as Ethernet frames, via two-wire lines such as telephone subscriber lines.

BACKGROUND OF THE INVENTION

Computers and related devices are increasingly being connected into networks for communications between the devices. Typically, the networks comprise LANs (local area networks) which provide communications among devices within a relatively small geographical area, different LANs being interconnected via MANs (metropolitan area networks) and WANs (wide area networks). This has resulted in a global computer information network which is generally known as the Internet. The term "Network" is used herein to refer generically to this global computer information network and to any other network of computers and related devices.

Different technologies can be used to facilitate communications on any LAN and throughout the Network, the most common being Carrier Sense Multiple Access with Collision Detection (CSMA/CD) technology. This is documented in IEEE Standard 802.3 entitled "Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications" which has been adopted by the International Organization for Standardization (ISO). The 802.3 Standard is based on the 1985 Version 2 Standard for Ethernet and, although there are some differences including different use of a length/type field, the two Standards are largely interchangeable and can be considered equivalent as far as this invention is concerned. The term "CSMA/CD" is used herein to refer generically to this technology. Using CSMA/CD, packets of data are communicated in frames that are generally referred to as Ethernet frames. This term is also used herein, regardless of whether the frames comply with the 802.3 Standard or the Ethernet Standard (i.e. regardless of the value contained in the length/type field of the frame).

The OSI (Open Systems Interconnection) reference model established by the ISO defines packetized communications protocols in seven layers, of which Layer 1 is the physical layer which is concerned with the physical interfaces between devices and the communications medium, and Layer 2 is the data link layer which is concerned with sending and receiving blocks of data together with information for example for synchronization and error and flow control. For LANs, the data link layer is generally considered as comprising two sub-layers, referred to as the LLC (logical link control) layer and the MAC (medium access control) layer. The LLC layer (Layer 2) is addressed by IEEE Standard 802.2. The CSMA/CD Standards address communications at the MAC and physical layers (Layers 2 and 1).

A particularly convenient and popular physical medium for LAN communications is twisted pair wiring as is commonly used for telephone communications. Such wiring typically consists of 0.4 mm to 0.6 mm diameter (26 AWG to 22 AWG) unshielded wires twisted together in pairs in a multipair cable. For example, one of the options for the physical layer documented for CSMA/CD is referred to as 10BASE-T and provides baseband communications at a data rate of 10 Mb/s over twisted pair wiring. The performance specifications are generally met by up to 100 m (meters) of 0.5 mm telephone twisted pair wire without the use of a repeater. Longer wiring lengths are permitted as long as the performance specifications, in particular a maximum delay, are met.

Accordingly, devices that are located relatively close to one another, for example within a building, can be relatively easily connected in a LAN using twisted pair wiring. For CSMA/CD communications via the LAN and for access to the Network, each device is easily equipped with an Ethernet interface card, which is connected via a respective twisted pair of wires to a repeater or CSMA/CD hub, and with TCP/IP (Transmission Control Protocol/Internet Protocol) software that handles the packetized communications at Layers 3 and 4 of the OSI model (Network and Transport Layers, respectively).

Increasingly, access to the Network is required from devices that are relatively distant from existing Network facilities. For example, such devices may be located within residences and small businesses, and they may be isolated computers or they may be connected in a LAN that is not connected to the rest of the Network. Such devices may for example comprise general-purpose computers or specific-purpose devices such as a Network browser, game machine, and/or entertainment device, and may also comprise related and/or ancillary equipment such as workstations, printers, scanners, bridges, routers, etc. that it may be desired to connect to the Network. The generic term "terminal device" and its abbreviation "TD" is used below to embrace all such devices.

It is known to provide for access to the Network from a relatively distant terminal device, or TD, via a communications path between a router on the Network and the distant TD, the communications path typically being constituted by a telephone line.

A simple form of such a communications path is a serial link comprising modem communications via a conventional two-wire telephone line. At Layers 1 and 2 of the OSI model the CSMA/CD communication, which can not be used on the serial link because of its length and characteristics, is replaced for the communication with each distant TD by modem communications via the respective telephone line and a point-to-point protocol, such as PPP (Point to Point Protocol) or SLIP (Serial Link Internet Protocol). Currently, modem communications generally provide a maximum data rate of 28.8 kb/s, and may typically operate in practice at lower, fall-back, data rates such as 19.2 or 14.4 kb/s. Such data rates are increasingly insufficient to meet demands imposed on communications for Network access, in particular for rapid downloading of relatively large amounts of data, e.g. for graphics. In addition, use of such modem communications prevents simultaneous use of the telephone line for telephone communications. Furthermore, such a communications path is set up as a dialled connection via the public switched telephone network (PSTN), which involves the inconvenience to the distant TD user of having to establish the dialled connection and the disadvantage of long connection times via the PSTN.

An alternative form of telephone communications path comprises an ISDN (Integrated Services Digital Network) telephone line. This provides two 64 kb/s B-channels each of which can be used for carrying voice communications or data. A TD can be connected to the ISDN line via a terminal adapter, which can thereby provide a total bit rate of 128 kb/s for data on both B-channels, or 64 kb/s for data on one B-channel simultaneously with digital telephone voice communications on the other B-channel. While this provides a significant increase in data rate compared with using a conventional two-wire telephone line, it requires an ISDN telephone line which, in the relatively limited areas in which it is available, involves additional cost, and the connection still has the disadvantage of being a dialled connection via the telephone network. In addition, a terminal adapter is generally more costly than a modem. Furthermore, even data rates of 64 kb/s or 128 kb/s are likely to be increasingly insufficient with evolution of the Network.

Higher speed telecommunications lines may be available for lease to provide high data rate communications, but these are not economical for TDs in residences and most small businesses. Cable modems have also been proposed for providing Network access via coaxial (coax) or hybrid fiber-coax (HFC) cable television distribution networks that provide bidirectional communications. While such proposals offer the possibility of high data rates, they are also limited to their own serving areas and are likely to involve relatively high costs for both the modem equipment and the ongoing use of the service.

Accordingly, there is an increasing need to facilitate access from terminal devices to the Network at relatively low cost both for equipment and ongoing service, that is not restricted to particular areas, that provides for high data rates, and that desirably does not preempt telephone communications or require long connection times via the PSTN. An object of this invention is to address this need.

SUMMARY OF THE INVENTION

According to one aspect, this invention provides a method of communicating information packets to and from a CSMA/CD (Carrier Sense Multiple Access with Collision Detection) path via a bidirectional communications path, comprising the steps of: coupling a first end of the communications path to a first modem; communicating information packets between the CSMA/CD path and the first modem via a CSMA/CD interface; coupling a second end of the communications path to a second modem; communicating information packets and control information, for controlling operation of the second modem, from the first modem to the second modem via the communications path; and communicating information packets from the second modem to the first modem via the communications path under control of the control information; the control information providing half duplex communications on the bidirectional communications path.

The half duplex communications, which can alternatively be considered as time division duplex or time compression multiplex communications, avoid collisions or interference between information packets communicated in the two directions of communication on the communications path by ensuring that the communications in the two directions take place at different times.

Preferably each step of communicating information packets comprises enveloping them in information frames which also comprise error check fields for error checking of at least the enveloped information packets. Information relating to

operation of the modems, such as the control information from the first modem to the second modem and response information from the second modem to the first modern, can be included in at least some of the information frames and/or in further frames which comprise this information and an error check field for error checking of at least this information.

Preferably each information packet communicated between the modems via the communications path comprises at least address, length, and data fields of an Ethernet frame communicated via the CSMA/CD path; it desirably also comprises a frame check sequence of the respective Ethernet frame, and may further comprise a preamble and start frame delimiter of an Ethernet frame.

Advantageously, the communications path comprises a two-wire telephone subscriber line and the modems communicate said information packets via the line at frequencies greater than telephone signal frequencies, the method further comprising the steps of communicating telephone signals via the line and, at each end of the line, combining telephone signals and information packets to be communicated via the line, and separating telephone signals and information packets communicated via the line, using a diplexer.

The method can further comprise the step of multiplexing signals of the first modem for communicating information packets between the first modem and a plurality of second modems.

The method can further comprise the steps of monitoring errors in communicating said information packets between the first and second modems via the communications path, and determining operations of the first and second modems in dependence upon monitored errors. The step of determining operations of the modems in dependence upon monitored errors can comprise varying a signal bandwidth and/or a modulation method of the modems. This enables an optimum rate to be achieved for communicating information packets via any particular two-wire line.

The method can further comprise the step of communicating information packets between the second modem and a second CSMA/CD path via a second CSMA/CD interface.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be further understood from the following description with reference to the accompanying drawings, in which:

FIG. **1** schematically illustrates a known Network access arrangement;

FIG. **2** illustrates the known format of an Ethernet frame;

FIG. **3** schematically illustrates a Network access arrangement in accordance with an embodiment of this invention;

FIG. **4** schematically illustrates a Network access arrangement, providing for simultaneous telephone communications, in accordance with another embodiment of this invention;

FIG. **5** schematically illustrates a diplexer used in the arrangement of FIG. **4**;

FIG. **6** shows a graph illustrating frequency characteristics related to the arrangement of FIG. **4**;

FIG. **7** schematically illustrates a master modem provided in the Network access arrangements of FIGS. **3** and **4**;

FIG. **8** schematically illustrates a slave modem provided in the Network access arrangements of FIGS. **3** and **4**;

FIGS. **9** to **11** illustrate frame formats that can be used in Network access arrangements in accordance with embodiments of the invention;

FIGS. **12** to **14** are flow charts with reference to which operation of the master and slave modems is described; and

FIG. **15**, which is on the same sheet as FIG. **8**, schematically illustrates a combined unit which replaces a slave modem and Ethernet interface provided in the arrangement of FIG. **3**.

DETAILED DESCRIPTION

FIG. **1** illustrates elements of a known arrangement for access from a subscriber to the Network **10** via a conventional two-wire telephone line **12**. Subscriber equipment includes a terminal device (TD) **14** which for example is constituted by a personal computer (PC), and a modem **16** connected to the line **12** and for example providing a maximum data rate of 28.8 kb/s. Although shown separately from the TD **14**, the modem **16** can instead be incorporated therein. The modem **16** communicates with a modem in a pool of dial-up modems **18** with a dialled connection which is established in well-known manner via the PSTN **20** to which the telephone line **12** is connected. The modems in the modem pool **18** are connected via an Ethernet interface (ENET I/F) **22** to a router **24** which is connected to the Network **10** and hence can be considered to be a part of the Network, the Network **10** generally being considered to include all of the terminal devices connected to it.

An upper part of FIG. **1** illustrates protocols in accordance with which the arrangement operates. TCP/IP operates at OSI Layers 3 and 4 end-to-end throughout the entire Network and access arrangement, with TCP/IP software running on the TD **14**. At the MAC layer of OSI Layer 2, communications in the access arrangement between the Ethernet interface **22** and the TD **14** operate in accordance with a point-to-point protocol such as PPP or SLIP, and communications between the Ethernet interface **22** and the Network **10**, and within the Network **10**, comprise Ethernet frames as described below with reference to FIG. **2**. These frames can be carried in a wide variety of forms and via various physical media, for example as the Ethernet frames themselves on a CSMA/CD LAN, in ATM (asynchronous transfer mode) cells, in SONET (synchronous optical network) formats, and so on. For communications between the Network **10** and the TD **14**, the router **24** converts between the Ethernet frames of the Network and the serial communications on the line **12** between the modems **16** and **18**.

A generally similar arrangement to that of FIG. **1** is provided in the event that the telephone line is an ISDN line, except that the modem **16** is replaced by an ISDN terminal adapter and communications on the line are digital at a rate that can be 64 or 128 kb/s.

FIG. **2** illustrates the Ethernet frame at the MAC layer. It consists of, in order, a preamble field of 7 bytes or octets (8 bits) of alternating 1s and 0s starting with a 1; a start frame delimiter (SFD) field of 1 byte having the sequence 10101011; a destination address field of 6 bytes; a source address field of 6 bytes; a length or type field of 2 bytes described further below; a data field of 46 to 1500 bytes, and a frame check sequence (FCS) field of 4 bytes or octets constituted by a CRC (cyclic redundancy check) of the data packet constituted by the address, length or type, and data fields. Data of less than 46 bytes in a frame is padded to the minimum data field size of 46 bytes. In accordance with the 802.3 Standard, the length or type field represents the length of data in the data field up to the maximum of 1500 bytes. In accordance with the Ethernet Standard, the length or type field is a value greater than 1500 that represents the type of data packet, and IP data packets are identified by one specific type value in this field. Thus the two Standards are different but inter-operable in this respect. It follows from this format that each frame comprises a data packet of from 60 to 1514 bytes, together with overhead (preamble, SFD, and FCS fields) of 12 bytes.

In accordance with the CSMA/CD Standards, the bits of each Ethernet frame are communicated using Manchester coding (a 1 bit is encoded as a 01 sequence, and a **0** bit is encoded as a 10 sequence, in each case with a transition in the middle of the bit period) at a predetermined data rate which is typically 10 Mb/s. Any terminal device connected to a CSMA/CD LAN can transmit a frame to the LAN (Multiple Access) in accordance with a contention scheme which is summarized by the following steps:

1. Monitor the LAN (Carrier Sense).
2. When the LAN is idle, transmit.
3. While transmitting, monitor the LAN for a collision (Collision Detection) by comparing transmitted bits with what is received from the LAN.
4. When a collision is detected, continue transmitting for a short period so that all TDs on the LAN detect the collision (this is referred to as jamming). Wait a random period of time determined by a binary exponential back-off algorithm, then return to step 1 for retransmission.

The minimum and maximum Ethernet frame size, predetermined data rate, and characteristics and lengths of segments of the LAN are inter-related in a manner that ensures effective operation of this contention scheme. For a 10BASE-T LAN using twisted pair wiring, as explained in the background of the invention this results in a maximum segment length of the order of 100 meters.

The two-wire telephone line **12** in the arrangement of FIG. **1** is constituted by twisted pair wiring, but has a length which is invariably much greater than 100 meters. Typically the length may be a maximum of about 5500 meters, with an average length for telephone lines in North America of the order of 1700 meters. These lengths are much greater than the approximate 100 meter maximum for a 10BASE-T LAN, and propagation delays make it impossible for the contention scheme outlined above to operate over such distances of twisted pair wiring. Even if this were not the case, signal attenuation over these distances of twisted pair wiring would make it very difficult to provide any reliable detection of collisions. Accordingly, it is not practical to use CSMA/CD on the telephone line **12**. Instead, the serial link point-to-point protocols are used in conjunction with the modems **16** and **18** as discussed above to provide Network access, with the data rate and other limitations discussed in the background of the invention.

FIG. **3** illustrates a Network access arrangement in accordance with an embodiment of this invention which is described first below, and also illustrates variations of this which are described subsequently below.

In FIG. **3**, a TD **14** of a subscriber is again connected to the Network **10** via a two-wire telephone subscriber line **12** which in this arrangement, as in the arrangement of FIG. **1**, is not being used for telephone communications. The TD **14** in this arrangement is connected to the line **12** via an Ethernet interface (ENET I/F) **30** and a modem **32**. The interface **30** is a conventional Ethernet interface which, although shown separately from the TD **14** in FIG. **3**, can be conveniently incorporated into the TD **14** either on a plug-in card or as a permanent part of the TD **14**. The interface **30** is the same as would be provided for connecting the TD **14** directly to a CSMA/CD LAN. The modem **32** has a form for example as described in detail below with reference to FIG. **8**, and has an Ethernet interface that is connected to the

interface **30**, and a two-wire line interface that is connected to the line **12**. Conveniently, the connection between the Ethernet interface **30** and the modem **32** is a 10BASE-T connection using twisted pair wiring. The modem **32** is referred to below as a slave modem as explained further below. The Ethernet interface **30** provides a Network address for the TD **14** as is well known. Similarly, the Ethernet interface within the modem **32** provides this with a Network address. Although the slave modem **32** is shown separately from the interface **30** and the TD **14**, the modem **32** can be physically combined with the Ethernet interface **30** for example as described below with reference to FIG. **15**, and can be incorporated into the TD **14**.

At its other end, for example at a PSTN central office (CO) or remote terminal (RT), the two-wire telephone line **12** is connected to a modem **34** which is referred to as a master modem and an example of which is described below with reference to FIG. **7**. The modem **34** also has a 10BASE-T Ethernet interface which provides the master modem with a Network address. This interface is connected via twisted pair wiring **36**, an Ethernet switch **38**, and a router **40** to the rest of the Network **10** in known manner. As is well known, functions of the switch **38** and router **40** can be combined in a single device referred to as a brouter.

An upper part of FIG. **3** illustrates, in a similar manner to FIG. **1**, protocols in accordance with which the Network access arrangement operates. As in the arrangement of FIG. **1**, TCP/IP operates at OSI Layers 3 and 4 end-to-end throughout the entire Network and access arrangement, with TCP/IP software running on the TD **14**. At the MAC layer, communications within and between the Network **10**, router **40**, switch **38**, and master modem **34** comprise Ethernet frames as described above. Similarly, communications between the slave modem **32** and the Ethernet interface **30** comprise Ethernet frames as described above, and the TD **14** operates in exactly the same known manner as it would if the interface **30** were connected directly to a LAN.

Communications between the master modem **34** and the slave modem **32** are carried out in accordance with a new point-to-point protocol which uses collision avoidance to communicate Ethernet frames between the modems. This protocol is described below and for convenience is referred to herein as ECAP (Ethernet frame Collision Avoidance Protocol). It is observed that this protocol operates only between the modems **32** and **34**, and hence need not be known to, and does not change the operation of, the TD **14** or the rest of the Network **10**. The protocol and modems simply serve to replace a direct (short-distance) connection between the interface **30** and the twisted pair wiring **36** by a remote connection via the (much greater distance) two-wire line **12**. Thus although as described here the line **12** is a telephone subscriber line, it can be appreciated that the same arrangement of master and slave modems operating in accordance with this new protocol can be used to communicate Ethernet frames via any twisted pair wiring which is too long to permit conventional 10BASE-T or similar LAN interconnections.

FIG. **3** also illustrates a management device **42**, for example a computer, coupled to the Ethernet switch **38** for providing operations, administration, management, test, and other functions relating to the communications in known manner. In order to provide communications via multiple lines **12** to multiple subscribers, preferably the master modem **34** contains multiplexing functions as described below with reference to FIG. **7**, and other master modems, one of which is illustrated in FIG. **3** and referenced **34'**, are connected to the switch **38** similarly to the modem **34**.

At the subscriber, one or more further arrangements of a slave modem **32'**, Ethernet interface **30'**, and TD **14'** can be similarly connected to the same two-wire line **12** as shown by a dashed line connection **44**. Alternatively (or in addition), and generally more desirably, as shown by a dashed line connection **46** the 10BASE-T connection of the slave modem **32** can be connected to a bridge **48** of known form, to which a plurality of TDs **14"** can be connected via their respective Ethernet interfaces (E I/Fs) in known manner to provide a subscriber LAN. These arrangements can be extended as desired in known manner.

It can be seen from the above description that embodiments of the invention are centered on the arrangement and functioning of the modems **32** and **34**. Before describing embodiments of these in detail, a further Network access arrangement is described below with reference to FIG. **4**. This further arrangement illustrates that the communications on each line **12** can comprise not only the data communications for the Network as described herein but also conventional telephone communications.

Referring to FIG. **4**, this illustrates the master and slave modems **34** and **32** respectively, with 10BASE-T interfaces to twisted pair wiring **36** and **46** respectively as described above, coupled via a two-wire subscriber line **12** which also serves for conventional telephone connections between a subscriber telephone **51** and a telephone CO or RT **50** connected to the PSTN. To this end, a passive diplexer **52** is provided at each end of the two-wire line **12**, the two diplexers **52** conveniently having the same form and being for example as described below with reference to FIG. **5**. Thus at a head end of the line **12** the CO or RT **50** and the master modem **34** are connected via a diplexer **52** to the line **12**, and at a subscriber end of the line **12** the subscriber telephone **51** and the slave modem **32** are connected to the line **12** via a diplexer **52**. As also shown in FIG. **4**, the master modem **34** can be multiplexed for other telephone subscriber lines **12'** to which it is similarly connected via respective diplexers **52'**. It can be appreciated that diplexers can be similarly provided in the arrangement of FIG. **3** to permit simultaneous telephone and Network communications.

FIG. **5** illustrates a simple form of the diplexer **52**, which comprises a d.c. and low pass filter (LPF) **54** between a two-wire connection to the line **12** and a two-wire connection to the telephone **51** or CO or RT **50**, and a d.c. isolator and high pass filter (HPF) **56** between the two-wire connection to the line **12** and a two-wire connection to the modem **32** or **34**. As illustrated in FIG. **5**, the LPF **54** can comprise one or more balanced filter sections comprising series inductors (which pass the telephone loop current) and shunt capacitors, and the HPF **56** can comprise two series capacitors having a capacitance such that they do not represent a significant load to the line **12**. More complicated forms of diplexer **52** can be provided as desired.

The graph in FIG. **6** illustrates the low frequency spectrum **60** of analog telephony signals, and two high frequency spectra **62** and **64** for Network communications. A desirable response **66** for the LPF **54** of the diplexer **52** separates the low frequency telephony signals on the two-wire line **12** from the Network communications signals on the same line **12**. It can be seen from this illustration that the telephony and Network communications signals occupy substantially different frequency bands and hence are easily separated by the diplexers **52**.

In FIG. **6**, the spectra **62** and **64** relate to two different signal bandwidths which can be used for the Network communications. For example, the relatively wide bandwidth spectrum **62** can correspond to a modulation method

with a symbol or clock rate of 3 MHz, and the relatively narrower bandwidth spectrum **64** can correspond to a modulation method with a symbol or clock rate of 300 kHz. Other signal bandwidths, not shown, can be similarly provided. The use of different bandwidths and modulation methods is described further below.

FIG. **7** illustrates a form of the master modem **34**, including optional but desirable multiplexing for a plurality of two-wire lines. The master modem includes an Ethernet interface **70** of known form providing a 10BASE-T connection to the twisted pair wiring **36** and providing (for example from a read-only memory within the interface **70**) a Network address for the master modem. The interface **70** is connected to a control unit **72** of the master modem, to the input of a FIFO (first in, first out) buffer **74** for buffering downstream Ethernet frames supplied from the Network via the wiring **36** and the interface **70**, and to the output of a FIFO buffer **76** for supplying upstream Ethernet frames via the interface **70** and the wiring **36** to the Network. An output of the buffer **74** is coupled via a modulator **78** and a downstream demultiplexer **80** (constituted by switches) to a respective one of the multiplexed two-wire lines **12** via a respective isolating transformer (TR) **82**, the output of the modulator **78** providing a matched termination for the line **12**. An upstream multiplexer **84** (constituted by switches) has inputs also coupled to the lines **12** via the transformers **82**, and has an output coupled via a high pass filter (HPF) **86** which provides a matched termination for the respective line **12** to which it is connected via the multiplexer **84**. An output of the HPF **86** is connected to an input of a demodulator **88** having an output connected to an input of the buffer **76**. The transformers **82** can also provide a balun function between the balanced lines **12** and the demultiplexer **80** and multiplexer **84**.

The demultiplexer **80** and multiplexer **84** are addressed by the control unit **72** via address lines **90** and **92** respectively to provide downstream frames to and to receive upstream frames from respective ones of the lines **12**. The addresses on the lines **90** and **92** are generally different for efficient data flow in the downstream and upstream directions, but they can be the same for example for loopback testing of a slave modem **32**. To provide different logical buffers for frames in the buffers **74** and **76** associated with the respective lines **12**, the buffers **74** and **76** are also addressed via the address lines **90** and **92** respectively. A store **94** is also addressed with the upstream multiplexer address on the lines **92** to provide to the demodulator **88** stored data, such as echo coefficients and signal amplitude level, relating to the respective line **12** to facilitate fast acquisition (recognition of the preamble of a frame) by the demodulator **88**. A store **95** is similarly addressed with the downstream demultiplexer address on the lines **90** to provide to the modulator **78** stored data to determine a signal transmission level and possibly frequency characteristics for the respective line **12**. Information for the stores **94** and **95** is determined, and the stores are updated, by the control unit **72** in known manner. Control lines **96** and **98** are provided between the control unit **72** and the modulator **78** and demodulator **88** respectively for communicating control information.

FIG. **8** illustrates a complementary form of a slave modem **32**. The slave modem includes an Ethernet interface **100** of known form providing a 10BASE-T connection to the twisted pair wiring **46** and providing (for example from a read-only memory within the interface **100**) a Network address for the slave modem. The interface **100** is connected to a control unit **102** of the slave modem, to the input of a FIFO buffer **104** for buffering upstream Ethernet frames supplied from the TD via the wiring **46** and the interface **100**, and to the output of a FIFO buffer **106** for supplying downstream Ethernet frames via the interface **100** and the wiring **46** to the TD. An output of the buffer **104** is coupled via a modulator **108**, a current generator **110**, and an isolating transformer **112** to the two-wire line **12**. The transformer **112**, which can also provide a balun function for the balanced line **12**, is also coupled via a high pass filter **114** and a demodulator **116** to an input of the buffer **106**. The current generator **110** provides a high output impedance to avoid loading of the line **12**, and the HPF **114** provides a matched termination of the line **12**, so that these can both be connected to the line **12** without any switching. This enables loopback testing of the line **12** from the control unit **102**. Control lines are provided between the control unit **102** and the buffers **104** and **106**, modulator **108**, and demodulator **116**.

It can be appreciated that, apart from the functions related to the multiplexing and switching for a plurality of lines **12**, and the operation of the modems as described below, the master modem **34** and the slave modem **32** are similar, and the arrangement of the slave modem shown in FIG. **8** could also be used as a master modem for a single line **12**.

In each of the modems **32** and **34** the modulator, demodulator, and related functions are conveniently implemented in known manner using one or more DSPs (digital signal processors) with analog-digital conversion in known manner. DSPs can be conveniently controlled to provide an arbitrary number of different signal bandwidths for example as illustrated by the spectra **62** and **64** in FIG. **6**. Conveniently the DSPs provide a common lower frequency limit of about 10 kHz for all of the signal bandwidths as shown in FIG. **6**, with the different bandwidths being determined by the symbol or clock rate as described above. The particular modulation method that is used is relatively arbitrary, but conveniently the DSPs in the modems are programmed to select any of a plurality of modulation methods, for example 16QAM (quadrature amplitude modulation), QPSK (quadrature phase shift keying), and BPSK (binary phase shift keying), providing different numbers of bits per symbol. These particular methods and numbers are given only by way of example, and other modulation methods, such as VSB (vestigial sideband), carrierless amplitude-phase, and DMT (discrete multi-tone) modulation, may be used instead, numerous different numbers of bits per symbol may be used, and the signal bandwidths may be arbitrarily defined (e.g. with different low-frequency cut-offs) as desired.

The master and slave modems communicate Ethernet frames downstream (from the master modem **34** to the slave modem **32**) and upstream (from the slave modem **32** to the master modem **34**) in a manner described in detail below. Briefly, this communication involves half-duplex transmission using a collision avoidance protocol (ECAP) in which the master modem **34** has priority and control over the slave modem **32**. Thus the master modem **34** determines when to send information downstream via the line **12**, and informs the slave modem when it is permitted to send information upstream via the line **12**. To facilitate these communications, the information sent via the line **12** comprises not only the data packets of Ethernet frames for Network communications but also control packets downstream and response packets upstream between the master and slave modems. These packets are incorporated into ECAP frames examples of which are described below with reference to FIGS. **9** to **11**. The control units **72** and **102** in the master and slave modems perform the necessary conversions between the Ethernet frames and ECAP data frames, and generate and respond to the ECAP control and response frames.

FIG. 9 illustrates an ECAP data frame which comprises overhead information O/H, followed by an Ethernet frame in exactly the same form as described above with reference to FIG. 2, followed by a check sequence CHK. The O/H field for example consists of a few bytes comprising a preamble and start-of-frame (SOF) indication of a suitable form for the modulation method in use by the master and slave modems, possibly followed by other information such as an ECAP frame sequence number for frame identification in known manner (e.g. for identifying frames for acknowledgement or retransmission). The check sequence CHK conveniently comprises a CRC sequence which can be produced in exactly the same manner as the FCS field of the Ethernet frame, the CRC operating on all of the information in the ECAP frame following the SOF indication up to and including the FCS at the end of the Ethernet frame. Thus as shown in FIG. 9 the Ethernet frame is enveloped, intact and without any change, within the ECAP frame.

Alternatively, as illustrated in FIG. 10, the preamble and SFD fields can be stripped from the Ethernet frame and only the remainder of the Ethernet frame (i.e. the data packet and FCS field) incorporated into the ECAP frame between the overhead field O/H and the check sequence CHK. In this case the preamble and SFD fields of the Ethernet frame are stripped for example by the control unit of whichever of the master and slave modems 34 and 32 is sending the frame, and is reinserted by the control unit of the receiving one of the modems 34 and 32 for forwarding the Ethernet frame to the respective Ethernet interface. This reduces slightly the amount of information to be transmitted via the line 12. Further reductions are possible if for example the pad, used for increasing data packets of less than 46 bytes to the minimum data field size of an Ethernet frame, can also be identified, stripped prior to sending the remainder of the frame between the modems 34 and 32, and reinserted at the receiving modem. However, it may be more desirable for the modems 34 and 32 always to communicate the entire data packet and FCS field of each Ethernet frame intact, to avoid risk of corrupting the Ethernet frame contents.

Thus whereas transmission of undersized frames is not possible in a CSMA/CD arrangement because of the nature of the contention scheme (they are generally interpreted as collisions), in this ECAP scheme collisions are avoided by the protocol between the master and slave modems so that short frames are not only permitted but can be desirable because they reduce the amount of information that must be communicated via the line 12.

To this end, FIG. 11 illustrates an ECAP control frame comprising a control packet to be communicated from the master modem 34 to the slave modem 32. The control frame comprises an initial overhead field O/H as described above, followed by a control packet described below, and the check field CHK providing a CRC sequence for all of the information in the ECAP frame following the SOF indication up to the end of the control packet. The control packet comprises destination and source address fields, a lengt/type field L/T, and a control field which is generally much shorter than the minimum 46 byte data field of an Ethernet frame and whose length is given by the contents of the field L/T. For such a control packet the destination and source addresses are the Network addresses of the slave modem 32 and the master modem 34, respectively.

Conversely, an ECAP response frame can have the same form as the control frame shown in FIG. 11, except that it contains a response field instead of the control field and the destination and source addresses are exchanged because the response frame is communicated from the slave modem 32 to the master modem 34.

Other ECAP frame formats can alternatively be provided to suit particular situations; for example for convenience or simplicity the control and response frames can have a fixed size and can be the same size as a data frame containing a minimum-size data packet. In addition, although as described here by way of example the control frames are separate from the data frames, control information can instead be incorporated into the ECAP data frames, desirably keeping the enveloped Ethernet frame contents intact, for example as an additional part of the overhead field O/H or between the CRC fields FCS and CHK.

The following description of an example of the collision avoidance protocol, with reference to FIGS. 12 to 14, assumes for simplicity and clarity that the master modem 34 typically sends a single data frame followed by a control frame downstream, and then waits for a response from the slave modem 32, and that the slave modem waits for these downstream frames and then typically sends a response frame followed by a single data frame upstream. It also assumes for simplicity that there is only one slave modem 32 connected to the line 12. Various modifications and extensions of this protocol, for example to accommodate multiple slave modems 32 connected to the same line 12, can be contemplated and some variations are described later below.

FIG. 12 illustrates a downstream transmitting flow chart for the master modem 34, and FIG. 13 illustrates an upstream receiving flow chart for the master modem 34, the master modem 34 being assumed here simply to alternate between the transmitting and receiving states for communications with a single slave modem 32. As already described, the master modem 34 can provide multiplexed operations for a plurality of slave modems, so that in practice the transmitting and receiving processes can take place simultaneously and independently in a multiplexed manner for a plurality of slave modems. FIG. 14 illustrates a downstream receiving and upstream transmitting flow chart for the slave modem 32. The operations in the modems in each case take place under the control of the respective control unit 72 or 102, and the master and slave modems differ in the manner in which these units operate as described below.

Referring to FIG. 12, in the transmitting sequence of the master modem 34 its control unit 72 initially determines in a decision 120 whether the downstream buffer 74 (for the respective line 12 and slave modem 32) is empty. If not, i.e. if there is at least one Ethernet frame to be sent from the buffer 74, then at a block 121 the next frame to be sent downstream from the buffer 74 is transmitted in an ECAP data frame as described above. At a block 122 the control unit 72 then sends a control frame as described above, and sets a timer for a response from the slave unit. In the event that the buffer 74 is empty as determined in the decision 120, then in a decision 123 the control unit 72 determines whether or not to send a control frame, if so proceeds to the block 122 to send a control frame, and if not returns to the start of the transmitting sequence. The decision 123 whether or not to send a control frame may depend upon various parameters which are monitored by the control unit 72, such as the fill state of the upstream receiving buffer 76, the state of the slave modem and the fill state of its upstream transmitting buffer 104, and the time since the previous control frame was sent to the slave modem. The contents of the control frame can comprise, for example, a request (poll) for the slave modem to transmit a frame of data upstream, a request for retransmission by the slave modem of a previous frame that has not been received correctly as determined by its check field CHK, control information such as operating parameters for the slave modem, and/or a request for status

information, such as the fills of the buffers **104** and **106**, from the slave modem.

Referring now to FIG. **14**, at a block **140** the control unit **102** of the slave modem **32** initially waits for a frame to be received from the master modem **34**. This waiting, and the subsequent operation of the slave modem in response to a received frame and operation of the master modem, ensures that collisions on the line **12** are avoided by giving control of the ECAP frames on the line **12** entirely to the master modem **34**. In response to receipt of a downstream frame from the master modem **34**, the control unit **102** of the slave modem determines in a decision **141** from the field CHK whether the frame has been received properly and, if not, at a block **142** sets a status flag to request retransmission of the frame and returns to the wait block **140**. If the frame has been properly received the control unit **102** proceeds to a decision **143**.

In the decision **143** the control unit **102** determines whether or not the destination address in the received frame is the address of the slave modem, and hence whether the frame is a control frame or a data frame. If the frame is determined to be a data frame, then in a block **144** the control unit **102** sets a status flag for acknowledgement of the frame, and in a block **145** the data frame is stored in the buffer **106** and a return is made to the wait block **140**.

If in the decision **143** the frame is determined to be a control frame, then in a block **146** the control unit **102** generates and sends a response frame upstream to the master modem. The contents of the response frame depend on the nature of the received control frame and the status of the slave modem, but for example can include status information, an acknowledgement of the received data frame (based on the acknowledgement status flag), a request for retransmission of an incorrectly received frame (based on the retransmission status flag), and buffer fills of the buffers **104** and **106**. In a decision **147**, the control unit **102** then determines whether a data frame is to be sent upstream, i.e. Whether the received downstream control frame included a retransmission request or a poll for an upstream data frame and such a data frame is available in the upstream transmission buffer **104**. If so, at a block **148** the control unit **102** sends the requested data frame from this buffer **104** upstream to the master modem. After the block **148**, or if no upstream frame is to be sent as determined in the decision **147**, a return is made to the wait block **140**.

Referring now to FIG. **13**, after the downstream transmitting sequence described above with reference to FIG. **12** the control unit **72** in the master modem **34** waits, as shown by a block **130**, for an upstream frame to be received or for the timer (set at block **122**) to time out. If an upstream frame is received, then in a decision **131** the control unit **72** determines from the field CHK whether the frame has been received properly and, if so, proceeds to a decision **132**. In the event that the timer times out in the block **130** or the frame is incorrectly received as determined in the decision **131**, then in a block **133** the control unit **72** updates a record of the communications status of the master modem with the slave modem. This status record contains various parameters of the communications such as those already discussed, for example the status of acknowledgements and retransmission requests, buffer fills, and operating parameters of the modems.

In the decision **132** the control unit determines, from the destination address of the received upstream frame and in accordance with its expectations based on the status of the communications, whether this is a response frame (i.e. the destination address is the address of the master modem) as expected first from the slave modem, or a data frame for which a poll or retransmission request has been sent to the slave modem as described above, or whether the frame does not have the expected form (e.g. it is a data frame when a response frame is expected). In the latter case the communications status is updated in the block **133**, and the control unit **72** proceeds in a manner dependent upon the updated status. For example, from the block **133** the control unit returns from the upstream receiving sequence of FIG. **13** to the downstream transmitting sequence of FIG. **12**, and can send a control frame requesting retransmission of an upstream frame for which there has been a timeout from the block **130**, a CRC error as determined in the decision **131**, or an unexpected frame as determined in the decision **132**.

On receipt of an expected response frame, in a block **134** the communications status is updated accordingly, and in dependence upon a decision **135** either a return is made to the block **130** for a data frame expected following the response frame (a data frame is expected if it has been requested from the slave modem and the response frame has not indicated that the upstream transmitting buffer **104** is empty; the timer for the block **130** can be reset as desired) or the receiving sequence ends if no subsequent data frame is expected. On receipt of an expected data frame as determined in the decision **132**, in a block **136** the control unit **72** sets a status flag for acknowledgement of the frame, and in a subsequent block **137** the received data frame is stored in the upstream receiving buffer **76** and the receiving sequence ends. As already described above, at the end of the upstream receiving sequence the control unit **72** of the master modem **34** returns to the start of the downstream transmitting sequence already described.

The collision avoidance protocol as described above provides for an approximate one-to-one ratio of downstream and upstream Ethernet frames, and gives priority to the master modem and the transmission of downstream frames. This is desirable because the modem arrangement has no control over the supply from the Network of Ethernet frames incoming to the buffer **74**, and it is desirable to avoid overflow of this buffer which would result in a loss of data frames. Such a data frame loss can be accommodated by the TCP/IP operating at Layers 3 and 4 of the OSI model, but this is preferably avoided.

The same principles apply for upstream Ethernet frames incoming to the buffer **104** from the TD **14**, but in this case overflow of the buffer **104** can be prevented by the Ethernet interface **100** of the slave modem **32**, under the control of the control unit **102** in the event that the buffer **104** is about to overflow, jamming the 10BASE-T connection on the wiring **46** by transmitting a dummy signal to it. As discussed in the introduction, jamming is a well-known process for ensuring that a collision detected at one device on a CSMA/CD LAN is also detected by all other devices on the LAN, but in this case the jamming is triggered differently, by the potential overflow of the buffer **104**. The jam or artificially created collision on the wiring **46** is detected by the TD **14** connected to this wiring, and the TD backs off for subsequent retransmission of the Ethernet frame in known manner. In this manner, a loss of upstream data frames due to overflow of the buffer **104** is avoided. The same situation can take place in the event that the wiring **46** is connected to the bridge **48** on a subscriber LAN as described with reference to FIG. **3**, but in this case either the bridge **48** must be a learning bridge to avoid passing to the slave modem **32** via the wiring **46** subscriber LAN frames not intended for upstream transmission, or such a learning function must be incorporated into the slave modem itself, otherwise jamming

of all frames on the subscriber LAN will occur when the buffer **104** is about to overflow.

To reduce the possibility of buffer overflow, especially of the buffer **74**, the collision avoidance protocol described above can provide dynamic variation of the ratio of the numbers of downstream and upstream frames, for example in dependence upon the fills of the buffers. The buffer fills are monitored as described above by the control unit **72**, either directly in the case of the master modem **34** or via status information in response frames from the slave modem **32**. If the fill of the buffer **74** is increasing, then the master modem can simply send a plurality of data frames downstream instead of each single data frame as described above with reference to FIG. **12**, before sending the control frame to poll the slave modem for an upstream data frame, thereby increasing the downstream to upstream data frame ratio. Conversely, if the buffer **74** is relatively empty and the buffer **104** is relatively full, the master modem can provide repeated polls for single upstream data frames without sending downstream data frames using the protocol exactly as described above, or more desirably the ECAP control frame poll can be arranged to indicate to the slave modem a number of data frames that it is requested to transmit upstream in response to particular polls, with the slave modem responding accordingly.

It can be appreciated from the description above that the collision avoidance protocol ensures that the modems **34** and **32** operate in a half-duplex manner for communications between them via the line **12**, with the total transmission capacity of the line being shared, preferably dynamically dependent upon buffer fills as described above, between the downstream and upstream directions of transmission. The protocol can be refined, from its basic form as described above, in various ways to maximize the efficiency with which the total transmission capacity is used. For example, such refinements can include provisions for sending multiple data frames successively in either direction as described above, concatenating or merging control and/or data frames sent in the same direction, and advancing the timing of downstream frame transmission from the master modem in view of the loop delay on the line **12** (which can be measured in known manner by the master modem) and the knowledge in the master modem control unit **72** of what upstream frames are expected from the slave modem.

This total transmission capacity on the line **12** can also be varied dynamically by the master modem **34** in dependence upon monitored operating conditions, as explained further below.

As described above, the modulation and demodulation functions in the master and slave modems are desirably implemented using DSPs. A clock rate of the DSPs can be changed to vary the signal bandwidth as shown by the two different spectra **62** and **64** in FIG. **6**. A high clock rate provides a corresponding large bandwidth, for example as shown by the spectrum **62** in FIG. **6**, providing a high symbol transmission rate on the line **12** between the modems **34** and **32**. However, this involves greater susceptibility to noise (a large noise bandwidth) and greater signal attenuation (which is dependent on frequency). Conversely, a lower clock rate provides a smaller bandwidth, for example as shown by the spectrum **64** in FIG. **6**, providing a lower symbol transmission rate on the line **12** with less susceptibility to noise and less signal attenuation. Considered generally, higher symbol rates on the line **12** produce greater total transmission capacity and greater error rates, resulting in frames having to be retransmitted.

As also described above, the control unit **72** in the master modem **34** determines from the check field CHK of each received upstream frame whether the frame has been received correctly, and can monitor a proportion of correct upstream frames received. The control unit **72** can similarly monitor a proportion of correct downstream frames received by the slave modem **32** from information similarly available in the control unit **102** of the slave modem and communicated to the control unit **72** via the response frames. From such ongoing monitoring, the control unit **72** can determine dynamically whether the clock rate in current use for the DSPs is appropriate or should desirably be increased to increase the total transmission capacity on the line **12** or decreased to decrease the proportion of frames received in error. This can be determined either independently or in common for the upstream and downstream directions of transmission.

For example, if the control unit determines that a high proportion, more than an upper threshold value of for example 95 to 99%, of frames are received correctly, then it can decide to increase the DSP clock rate and hence the total transmission capacity. To this end it generates a control frame which is sent from the master modem to the slave modem instructing the slave modem to adopt a new, higher, clock rate for future frames, the slave modem responds accordingly, and the master modem switches its own clock rate. Conversely, if the control unit determines that a low proportion, less than a lower threshold value of for example 50 to 75%, of frames are received correctly, then it can decide to decrease the DSP clock rate to reduce errors. To this end it generates a control frame which is sent from the master modem to the slave modem instructing the slave modem to adopt a new, lower, clock rate for future frames, the slave modem responds accordingly, and the master modem switches its own clock rate. It can be appreciated that the threshold levels can be determined to provide a desired hysteresis for changing the clock rate, and that they may be adaptively adjusted by the control unit **72** in dependence upon the results of previous changes in clock rate.

The total transmission capacity is determined not only by the symbol transmission rate on the line **12** but also by the number of bits per symbol, and hence by the modulation method that is used. As described above, the modem DSPs can provide any of a plurality of modulation methods, such as 16QAM, QPSK, and BPSK providing respectively 4 bits, 2 bits, and 1 bit per transmitted symbol. In a similar manner to that described above for dynamically varying the symbol transmission rate, the control unit **72** can also or instead dynamically vary the modulation method. A determination as to whether to change the symbol transmission rate and/or the modulation method can be made by the control unit **72** in dependence upon various parameters such as the current symbol transmission rate and modulation method, a history of these operating parameters, the error rate, and monitored characteristics of the line **12** such as delay, signal levels, and echo parameters.

In any event, the dynamic variations discussed above enable the control unit **72** in the master modem **34** to determine and use, at any particular time for any particular line **12** to which it is connected, a clock rate and modulation method to provide an optimal total transmission capacity on that line. It can be appreciated that this optimal capacity may well include a certain proportion of frames that are in error and must be retransmitted, and that this is accommodated by the collision avoidance protocol as already described above.

The total transmission capacity can vary over an extremely wide range. For example, for a short line **12** and under good conditions, the modulation method may be 16QAM and the clock rate 3 MHz to provide a total

transmission capacity of the order of the 10BASE-T bit rate of 10 Mb/s. Conversely, for a long line **12** (it is observed here that the line **12** must be unloaded to permit communication of signals at frequencies above the voice-band) and in poor conditions (e.g. in the presence of noise and crosstalk) the modulation method may be BPSK and the clock rate may be reduced to for example 30 kHz, thereby providing a total transmission capacity of about 25 kb/s (at for example 0.85 bits per Hertz to allow for excess bandwidth of the modem filters). However, it is noted that even this total transmission capacity is commensurate with the maximum bit rates of dial-up modems currently used to provide Network connections via conventional two-wire telephone lines. In practice, the total transmission capacity provided will be between these extremes, and will generally be substantially more than can be provided by currently used dial-up modems or on ISDN telephone lines.

It is also noted that the master modem **34** can be arranged to fall back to known modem communications methods in the event that it does not receive any ECAP response frames from a slave modem, so that the same master modem can operate alternatively with slave modems as described above or with conventional modems.

In use of the network access arrangement and protocol as described above, the master and slave modems and the line **12** simply serve to communicate Ethernet frames in both directions transparently between the wiring **36** and **46**. Accordingly, the subscriber is provided with a Network connection without any dialling process, and hence without involving a telephone connection via the PSTN, in the same way (as seen by the Network and by the subscriber) as if the wiring **36** and **46** were directly interconnected. As described above, this Network connection is established in a manner that is dynamically variable to provide an optimum total transmission capacity, which can be shared in a dynamically variable and optimized ratio of upstream to downstream data frames, for any prevailing conditions such as the characteristics of the line **12** and noise and crosstalk levels. For short lines **12**, the total transmission capacity is comparable with the bit rate of 10BASE-T LANS, so that there is no inherent deterioration of performance for communication of Ethernet frames. In addition, it is observed that because the frames on the line **12** are communicated in burst mode, there is statistically less energy on the line than would be the case for continuous data transmission on the same line, so that crosstalk with other lines in the same cable is reduced. Furthermore, the same line **12** can simultaneously carry conventional telephone signals, so that provision of the network access arrangement to a telephone subscriber does not necessitate the provision of an additional or separate telephone line.

Thus the use of the network access arrangement from a TD **14** is substantially the same as if the TD **14** were connected directly via an Ethernet interface to the Ethernet switch **38**. The TD **14** runs conventional software which, for initial access to the Network, in known manner sends information packets in Ethernet frames upstream, these packets containing for example the Network address of the management device **42** as the destination address and the Network address of the TD **14** as the source address. The packets are routed via the Ethernet switch **38** in known manner to the device **42**, and the switch **38** stores the address of the TD **14** for subsequent direction of Ethernet frames addressed to this address to this TD. In known manner, the device **42** either recognizes the source address of the TD **14** and provides a welcome message, or does not recognize it and initiates a registration process, and communications continue in known manner except that they take place via the modems **34** and **32** and line **12** instead of via a direct connection as is known.

In the embodiments described in detail above and as illustrated in FIG. **3** the slave modem **32** is separate from the Ethernet interface **30** connected to the TD **14** and includes its own Ethernet interface and Network address. While this is convenient in the case that the slave modem is connected to a subscriber LAN via the wiring **46**, it can be superfluous or undesirable in the event that the slave modem **32** is connected to only a single TD **14**, especially if the slave modem **32** and Ethernet interface **30** are merged together into a combined unit that may be incorporated into the TD **14** as would be desirable for example for an entertainment device. Even in the case of a subscriber LAN, the bridge **48** can be considered as a terminal device in which the slave modem **32** could be incorporated.

It can be seen, therefore, that the manner in which the slave modem **32** is ultimately connected to the TD **14** is relatively arbitrary as far as this invention is concerned, it only being necessary that the information be converted or translated between the Ethernet frames to and from the buffers **104** and **106** of the slave modem and whatever form is required for the connection to the TD **14** (for example, a PCM/CIA interface of known form), and that a Network address identify the TD, translator, and/or slave modem. Desirably, the slave modem **32** and the Ethernet interface **30** are merged into a combined unit, which can have a form for example as illustrated in FIG. **15**.

Referring to FIG. **15**, the combined unit has a similar form and operation to the slave modem **32** as described above with reference to FIG. **8**, and the same reference numerals are used to denote similar parts, except that the Ethernet interface **100** and wiring **46** of the slave modem of FIG. **8**, as well as the Ethernet interface **30** of FIG. **3**, are replaced by a data translator **150**. The translator **150** has an interface **152** to the control unit **102** and buffers **104** and **106**, and an interface **154** to the TD **14**, which are arranged and operate in the same manner as the corresponding parts of the known Ethernet interfaces **100** and **30** discussed above. Between these interfaces **152** and **154**, the unit **150** includes a minimized subset of the known circuits and functions of the Ethernet interfaces **100** and **30** necessary to translate data between the TD interface **154** and the Ethernet frame buffers **104** and **106**, and to provide a single Network address. This avoids the disadvantage of needing two Network addresses for the slave modem **32** and the Ethernet interface **30** respectively as in the embodiments of the invention described above, but makes it necessary to distinguish between ECAP control frames for the control unit **102** and ECAP data frames enveloping Ethernet frames containing data for the TD **14**.

Where the control frames and data frames are separate ECAP frames, this distinction can conveniently be provided by using the L/T field of the Ethernet frame. For an ECAP control frame, the L/T field can contain a pre-assigned (and otherwise unused) type having a value greater than the maximum value of 1500 for an Ethernet frame, which is recognized by the control unit **102** so that the control frame is not forwarded to the translator **150**. Alternatively, or in addition, as described above ECAP control information can be appended to Ethernet frames, for example in the overhead field O/H or between the FCS field of the enveloped Ethernet frame and the check field CHK of the ECAP frame. In either case the control information can be of a fixed size or it can include its own length field to indicate its size. The L/T field of the enveloped Ethernet frame is not changed, to avoid any risk of corrupting the Ethernet frame.

Although particular embodiments of the invention and various modifications have been described in detail, it should be appreciated that numerous other modifications, variations, and adaptations may be made without departing from the scope of the invention as defined in the claims.

What is claimed is:

1. A method of communicating information packets to and from a CSMA/CD (Carrier Sense Multiple Access with Collision Detection) path via a bidirectional communications path, comprising the steps of:

coupling a first end of the communications path to the CSMA/CD path via a first modem having a CSMA/CD interface coupled to the CSMA/CD path;

communicating said information packets between the CMSA/CD path and the first modem via said CSMA/CD interface,

coupling a second end of the communications path to a second modem;

communicating said information packets between the first and second modem via the communications path using half duplex communications controlled by the first modem;

communicating control information for controlling said half duplex communications via the communications path from the first modem to the second modem: and

wherein the communications path comprises a two-wire telephone subscriber line and wherein the modems communicate said information packets via the line at frequencies greater than telephone signal frequencies, the method further comprising the steps of:

communicating telephone signals via the line; and

at each end of the line, combining telephone signals and information packets to be communicated via the line, and separating telephone signals and information packets communicated via the line, using a diplexer.

2. A method as claimed in claim **1** and further comprising the step of multiplexing signals of the first modem for communicating information packets between the first modem and a plurality of second modems.

3. A method of communication information packets to and from a CSMA/CD (Carrier Sense Multiple Access with Collision Detection) path via a bidirectional communication path, comprising the steps of:

coupling a first end of the communications path to a first modem;

communicating information packets between the CSMA/CD Dath and the first modem via a CSMA/CD interface;

coupling a second end of the communications path to a second modem;

communicating information packets and control information, for controlling operation of the second modem, from the first modem to the second modem via the communications path;

communicating information packets from the second modem to the first modem via the communications path under control of the control information;

the control information providing half duplex communications on the bidirectional communications path; and

wherein the communications path comprises a two-wire telephone subscriber line and wherein the modems communicate said information packets via the line at frequencies greater than telephone signal frequencies, the method further comprising the steps of:

communicating telephone signals via the line; and

at each end of the line, combining telephone signals and information packets to be communicated via the line, and separating telephone signals and information packets communicated via the line, using a diplexer.

4. A method as claimed in claim **3** and further comprising the step of multiplexing signals of the first modem for communicating information packets between the first modem and a plurality of second modems.

5. Network access apparatus comprising:

a CSMA/CD (Carrier Sense Multiple Access with Collision Detection) interface for coupling to a CSMA/CD path;

a second interface for coupling to a bidirectional communications path;

a control unit for producing control information for controlling another apparatus coupled to the communications path so that communications via the communications path take place in a half duplex manner;

a first buffer arranged to buffer information packets received from the CSMA/CD path via the CSMA/CD interface and to supply buffered information packets via the second interface to the communications path; and

a second buffer arranged to buffer information packets received from the communications path via the second interface and to supply buffered information packets to the CSMA/CD path via the CSMA/CD interface.

6. Apparatus as claimed in claim **5** wherein the second interface comprises a modem for communicating modulated signals via the communications path.

7. Apparatus as claimed in claim **6** and including a plurality of said first and second buffers for buffering information packets for a plurality of bidirectional communications paths.

8. Network access apparatus comprising:

a CSMA/CD (Carrier Sense Multiple Access with Collision Detection) interface for coupling to a CSMA/CD path;

a second interface for coupling to a bidirectional communications path;

a buffer arranged to buffer information packets received from the communications path via the second interface and to supply buffered information packets to the CSMA/CD path via the CSMA/CD interface;

a control unit; and

another buffer arranged to buffer information packets received from the CSMA/CD path via the CSMA/CD interface and controlled by the control unit to supply buffered information packets via the second interface to the communications path;

wherein the control unit is responsive to control information, from another apparatus coupled to the communications path, received from the communications path via the second interface for controlling said another buffer so that communications via the communications path take place in a half duplex manner.

9. Apparatus as claimed in claim **8** wherein the second interface comprises a modem for communicating modulated signals via the communications path.

* * * * *

ADDENDUM E

US006587473B2

(12) **United States Patent**
Terry et al.

(10) **Patent No.: US 6,587,473 B2**
(45) **Date of Patent: *Jul. 1, 2003**

(54) **INFORMATION NETWORK ACCESS APPARATUS AND METHODS FOR COMMUNICATING INFORMATION PACKETS VIA TELEPHONE LINES**

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(73) Assignee: **Elastic Networks, Inc.**, Alpharetta, GA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **09/930,178**

(22) Filed: **Aug. 16, 2001**

(65) **Prior Publication Data**

US 2003/0002519 A1 Jan. 2, 2003

Related U.S. Application Data

(63) Continuation of application No. 09/251,939, filed on Feb. 18, 1999, now Pat. No. 6,327,264, which is a continuation of application No. 08/640,705, filed on May 1, 1996, now Pat. No. 5,912,895.

(51) **Int. Cl.**[7] **H04L 12/413**
(52) **U.S. Cl.** **370/445**; 375/222
(58) **Field of Search** 370/445, 447, 370/448, 431, 276, 279, 280, 293, 294, 446, 351–356; 375/222

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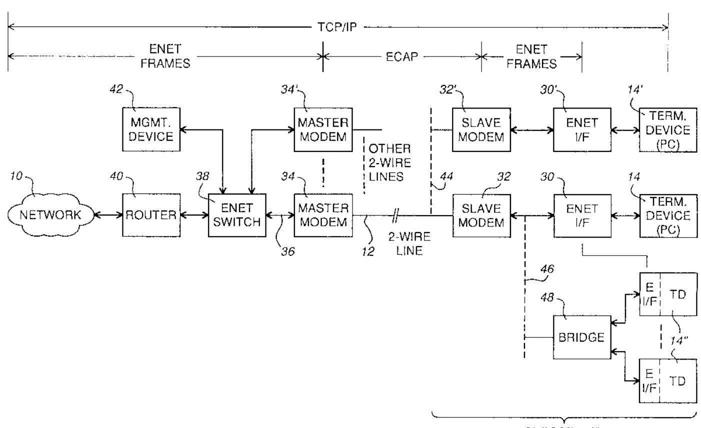
Primary Examiner—Ajit Patel
(74) *Attorney, Agent, or Firm*—Thomas, Kayden, Horstemeyer & Risley

(57) **ABSTRACT**

Access to a CSMA/CD (Carrier Sense Multiple Access with Collision Detection) network is provided via a telephone line by providing a master modem at the head end and a slave modem at the subscriber end of the line. The master modem provides a CSMA/CD interface to the network and controls half duplex communications with the slave modem via the line to avoid collisions of information packets on the line. The information packets are enveloped in frames on the line with error checking information; control information between the modems is contained in the same and/or in separate frames. The modulation method and signal bandwidth can be varied depending on errors to provide optimum communications capacity via any particular line, and a ratio of upstream to downstream information packets can be varied depending on buffer fills at the modems. The master modem can be multiplexed for multiple lines. The modulated signal frequencies are above telephone signal frequencies so that each line can be frequency diplexed for simultaneous telephone communications.

42 Claims, 8 Drawing Sheets



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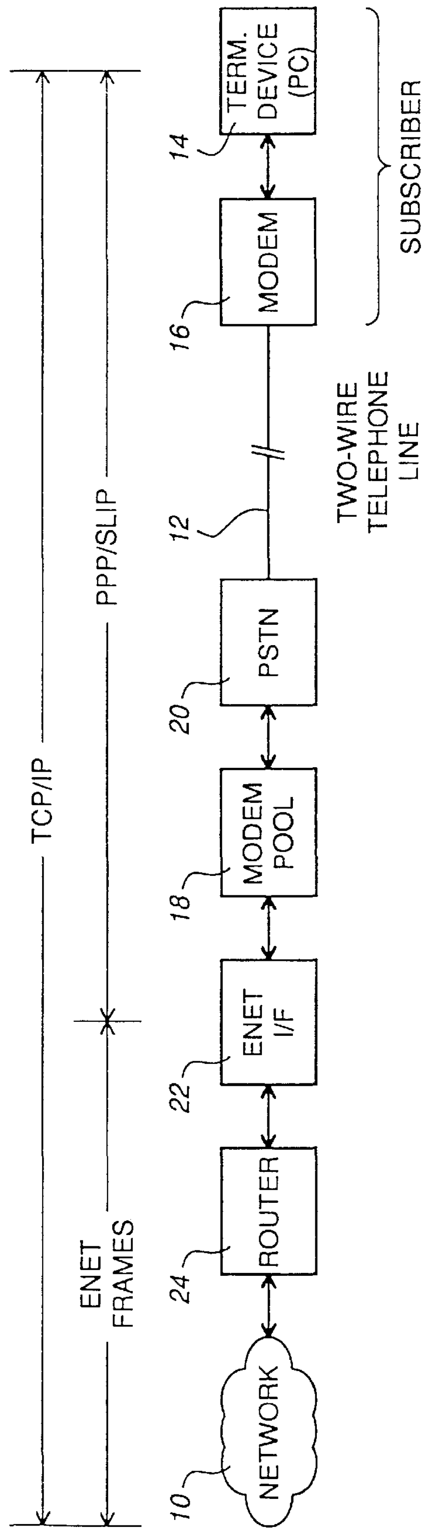


Fig. 1 PRIOR ART

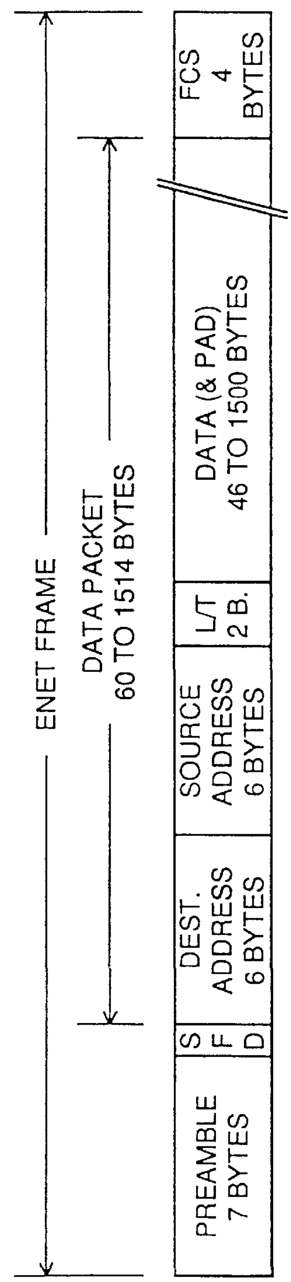


Fig. 2 PRIOR ART

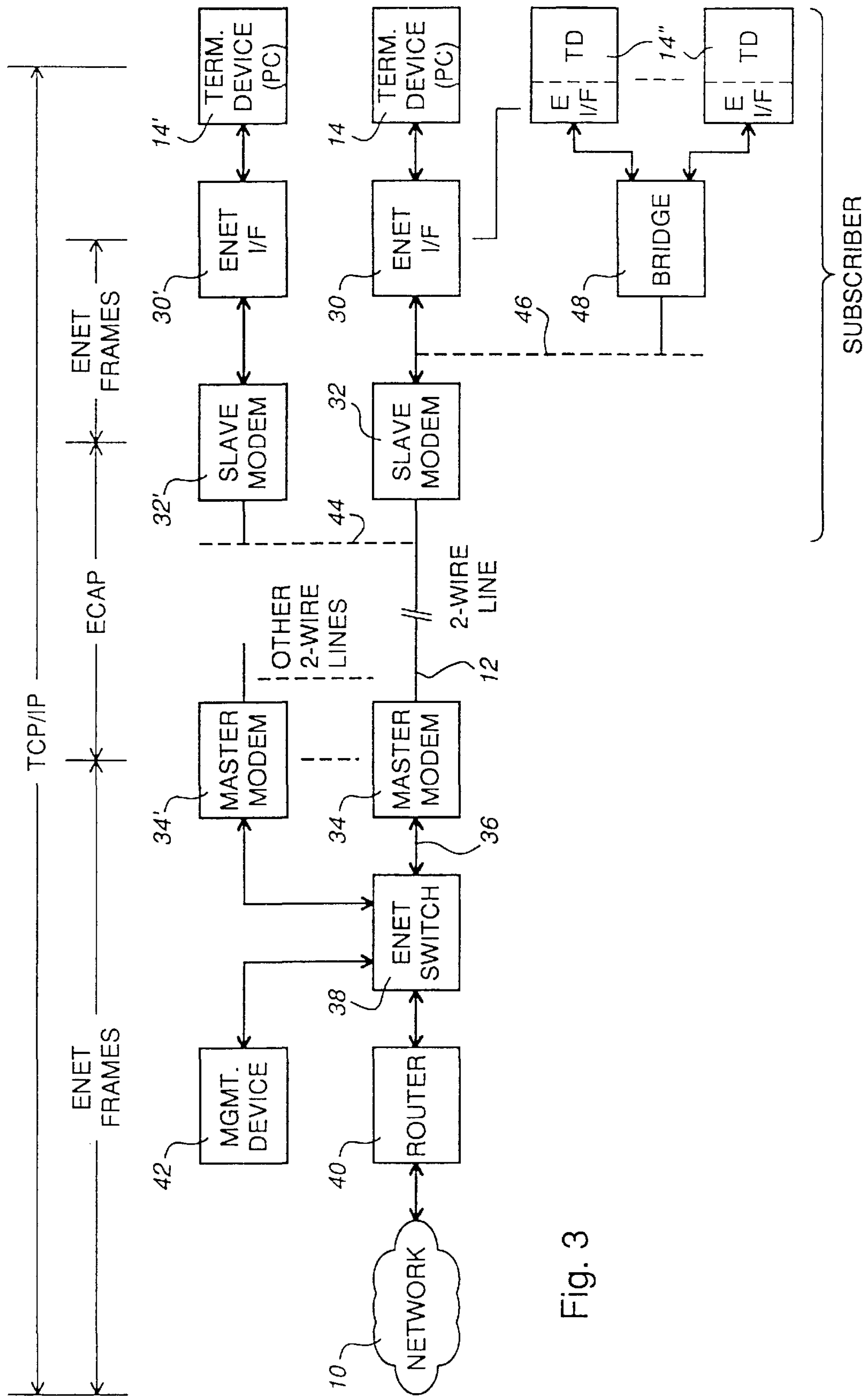

TCP/IP
ENET FRAMES
ECAP
ENET FRAMES
TERM. DEVICE (PC)
14'
ENET I/F
30'
SLAVE MODEM
32'
MASTER MODEM
34'
MGMT. DEVICE
42
TERM. DEVICE (PC)
14
ENET I/F
30
SLAVE MODEM
32
44
2-WIRE LINE
OTHER 2-WIRE LINES
12
MASTER MODEM
34
36
ENET SWITCH
38
ROUTER
40
NETWORK
10
TD
E I/F
14"
TD
E I/F
BRIDGE
48
46
SUBSCRIBER

Fig. 3

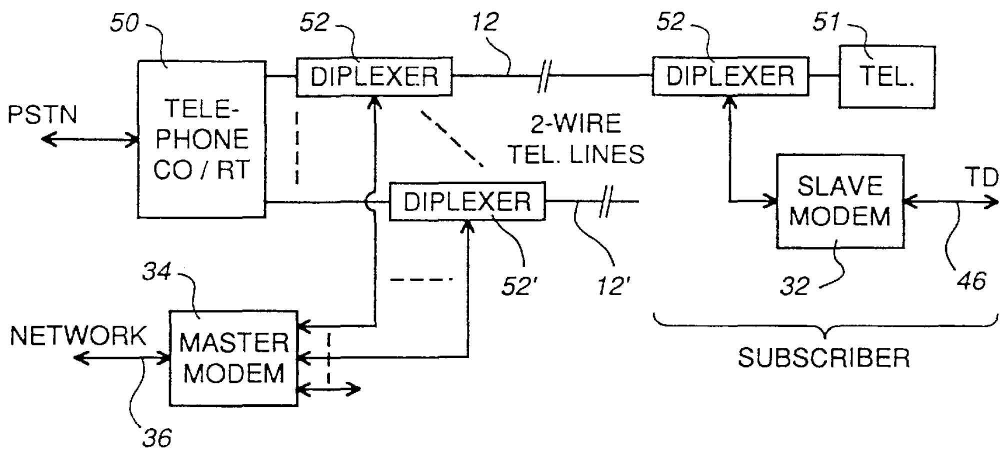


Fig. 4

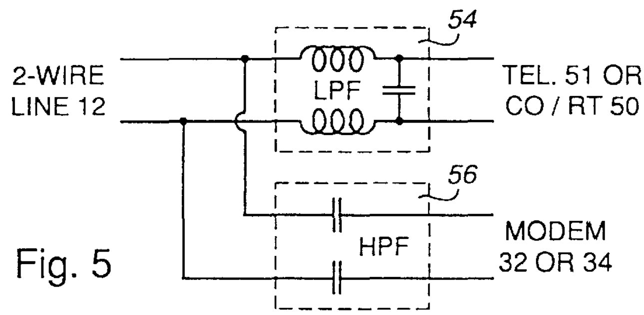


Fig. 5

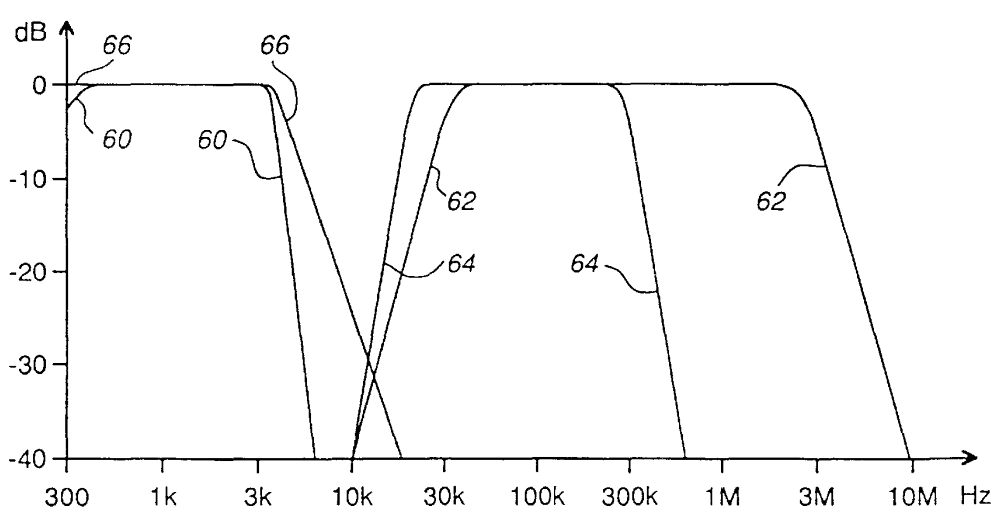


Fig. 6

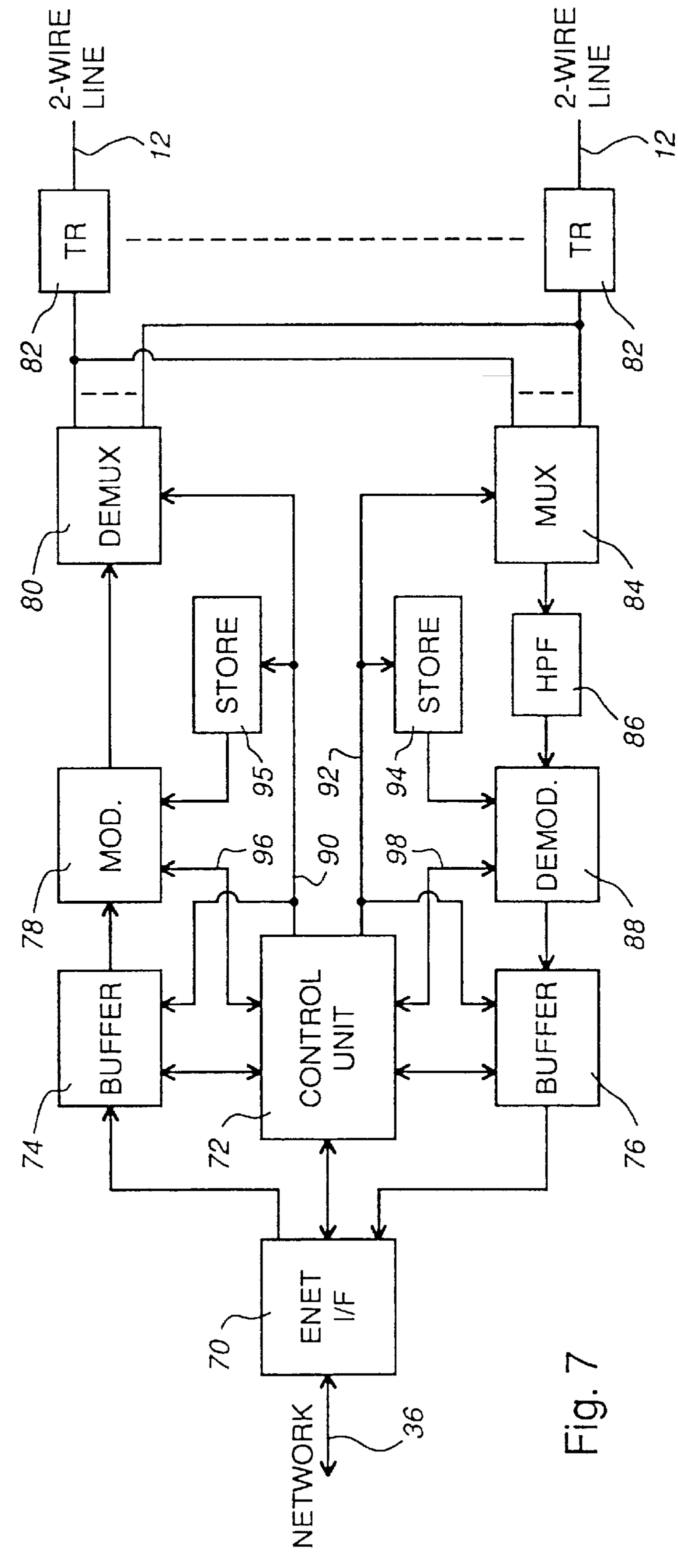

2-WIRE LINE
12
TR
82
DEMUX
80
MUX
84
STORE
95
STORE
94
HPF
86
92
MOD.
78
DEMOD.
88
96
90
98
BUFFER
74
CONTROL UNIT
72
BUFFER
76
ENET I/F
70
NETWORK
36

Fig. 7

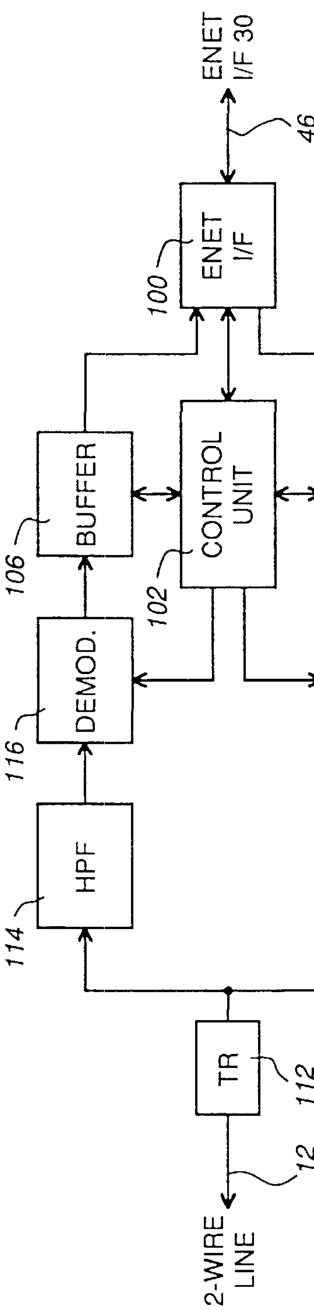

ENET I/F 30
46
ENET I/F
100
BUFFER
106
CONTROL UNIT
102
BUFFER
104
DEMOD.
116
MOD.
108
HPF
114
CURRENT GEN.
110
TR
112
12
2-WIRE LINE

Fig. 8

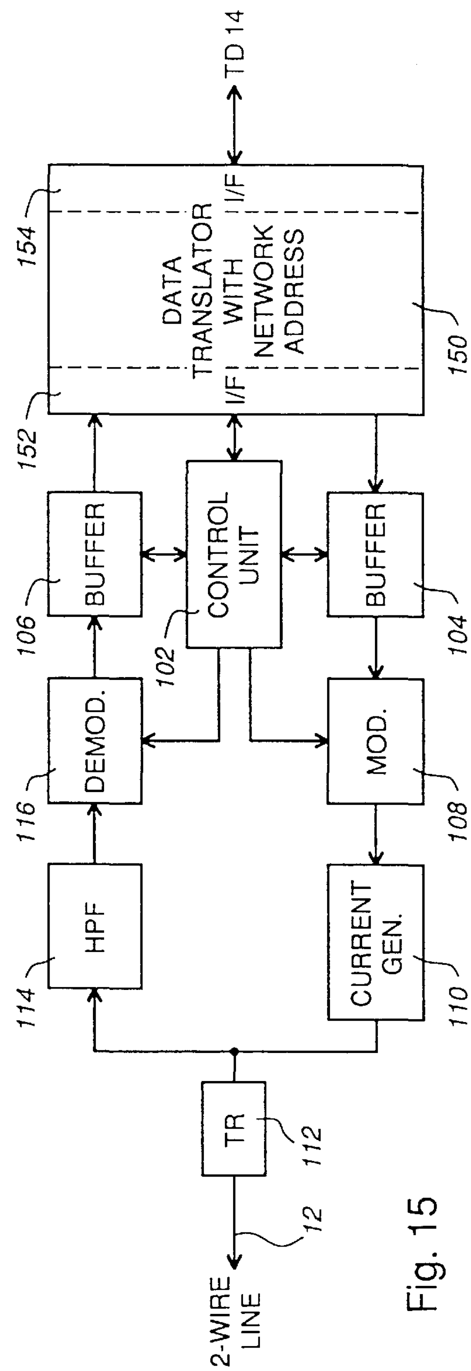

TD 14
154
I/F
DATA TRANSLATOR WITH NETWORK ADDRESS
150
I/F
152
BUFFER
106
CONTROL UNIT
102
BUFFER
104
DEMOD.
116
MOD.
108
HPF
114
CURRENT GEN.
110
TR
112
12
2-WIRE LINE

Fig. 15

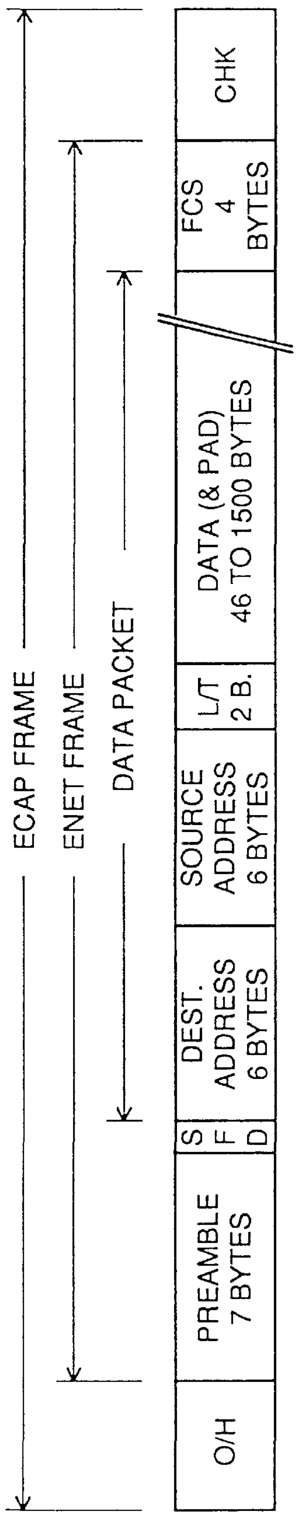


Fig. 9

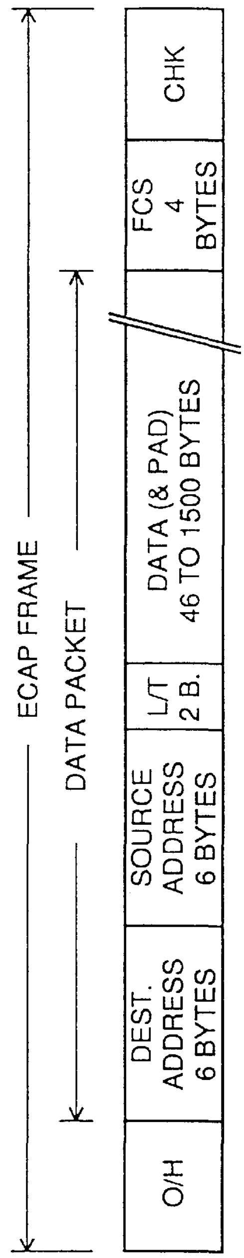


Fig. 10

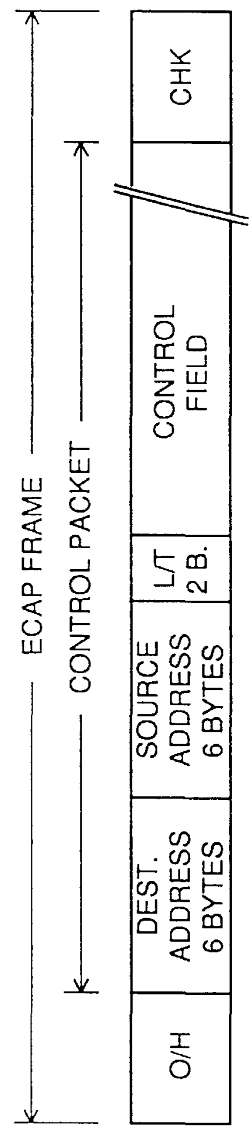


Fig. 11

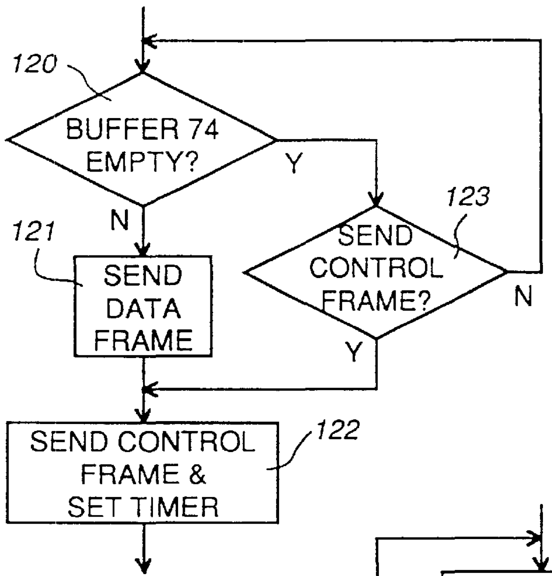

120
BUFFER 74 EMPTY?
Y
N
123
SEND CONTROL FRAME?
N
121
SEND DATA FRAME
Y
SEND CONTROL FRAME & SET TIMER
122

Fig. 12

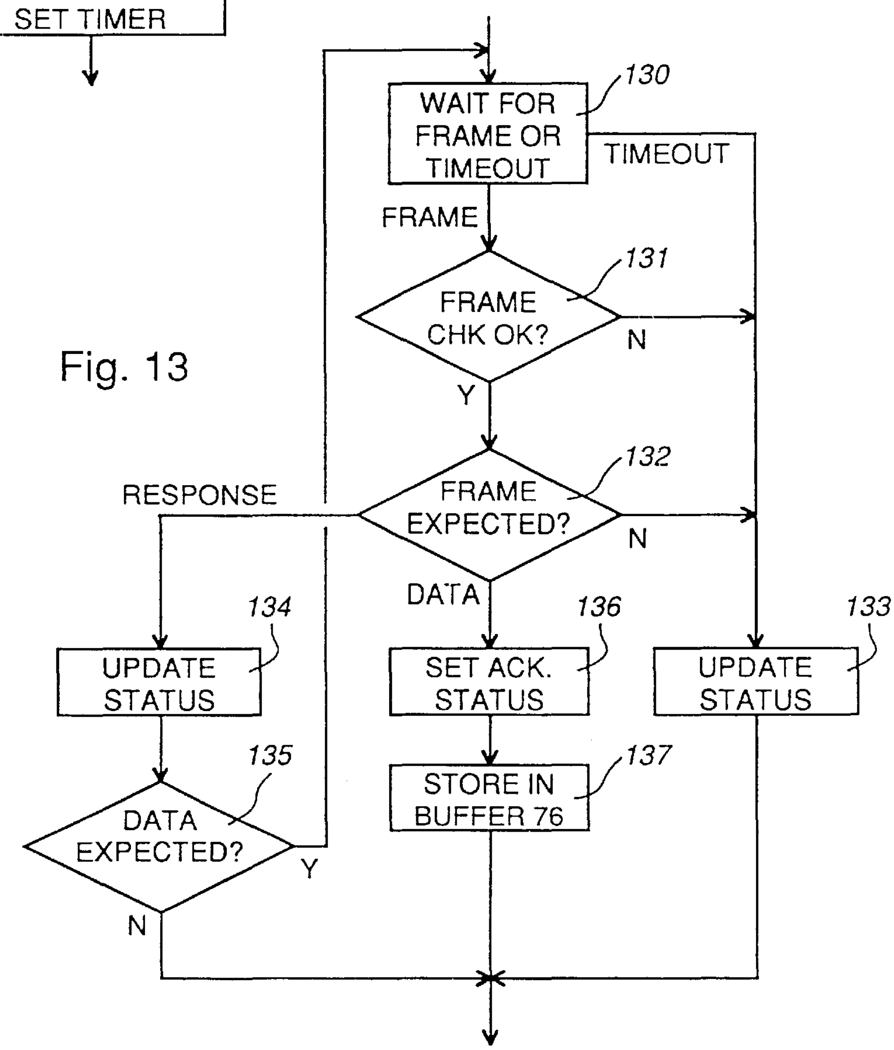
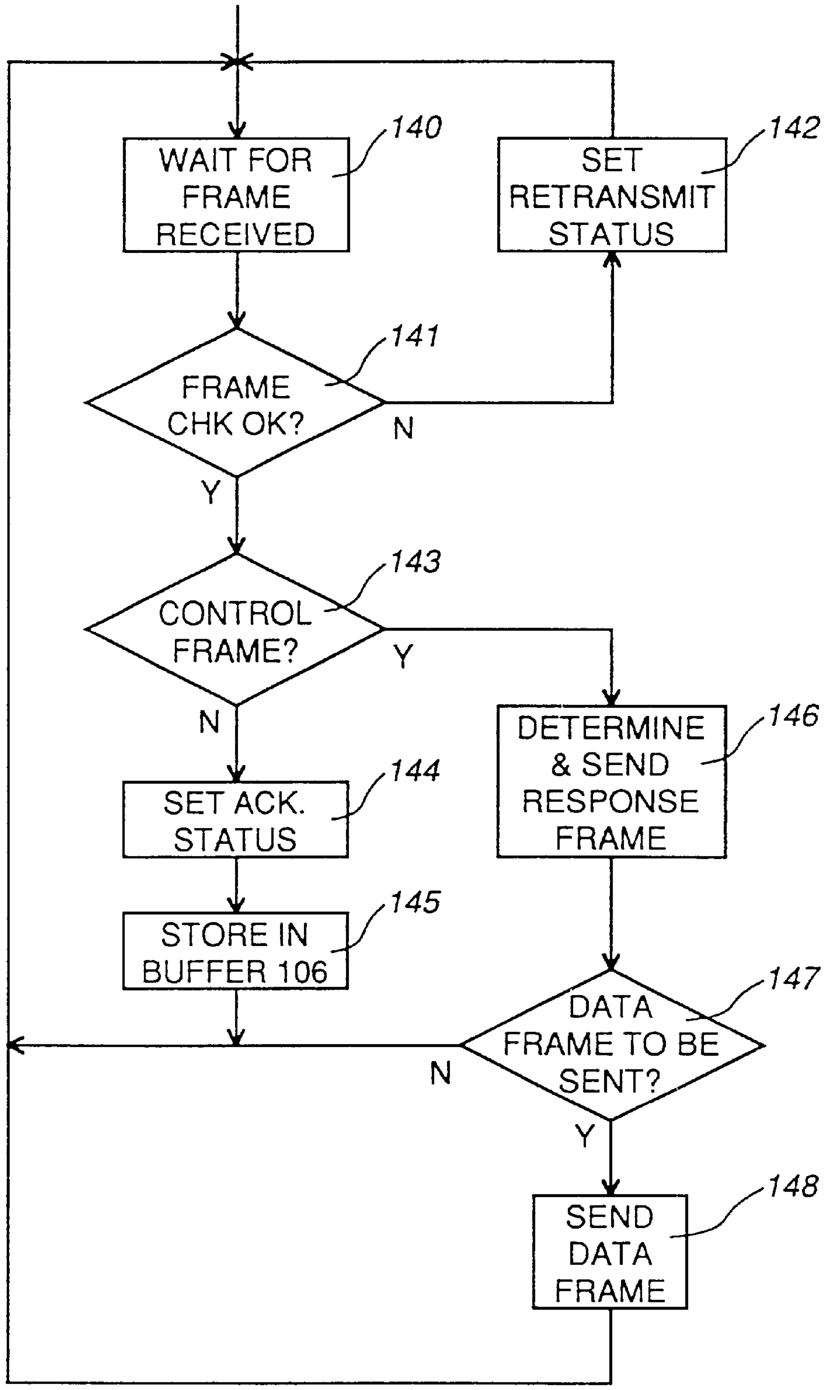

130
WAIT FOR FRAME OR TIMEOUT
TIMEOUT
FRAME
131
FRAME CHK OK?
N
Y
132
FRAME EXPECTED?
RESPONSE
N
DATA
134
UPDATE STATUS
136
SET ACK. STATUS
133
UPDATE STATUS
135
DATA EXPECTED?
Y
N
137
STORE IN BUFFER 76

Fig. 13



WAIT FOR FRAME RECEIVED
140
SET RETRANSMIT STATUS
142
FRAME CHK OK?
141
N
Y
CONTROL FRAME?
143
Y
N
DETERMINE & SEND RESPONSE FRAME
146
SET ACK. STATUS
144
STORE IN BUFFER 106
145
DATA FRAME TO BE SENT?
147
N
Y
SEND DATA FRAME
148

Fig. 14

INFORMATION NETWORK ACCESS APPARATUS AND METHODS FOR COMMUNICATING INFORMATION PACKETS VIA TELEPHONE LINES

This is a continuation of 09/251,939 U.S. Pat. No. 6,327,264, filed on Feb. 18, 1999, and issued on Dec. 4, 2001, which is further a continuation of 08/690,705 U.S. Pat. No. 5,912,895, filed on May 1, 1996, and issued on Jun. 15, 1999. This application claims benefit of and priority to both U.S. Pat. No. 6,327,264 and U.S. Pat. No. 5,912,895, which are both incorporated by reference in their entirety herein.

This invention relates to information network access, and is particularly concerned with apparatus and methods for communicating information packets, generally referred to as Ethernet frames, via two-wire lines such as telephone subscriber lines.

BACKGROUND OF THE INVENTION

Computers and related devices are increasingly being connected into networks for communications between the devices. Typically, the networks comprise LANs (local area networks) which provide communications among devices within a relatively small geographical area different LANs being interconnected via MANs (metropolitan area networks) and WANs (wide area networks). This has resulted in a global computer information network which is generally known as the Internet. The term "Network" is used herein to refer generically to this global computer information network and to any other network of computers and related devices.

Different technologies can be used to facilitate communications on any LAN and throughout the Network, the most common being Carrier Sense Multiple Access with Collision Detection (CSMA/CD) technology. This is documented in IEEE Standard 802.3 entitled "Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications" which has been adopted by the International Organization for Standardization (ISO). The 802.3 Standard is based on the 1985 Version 2 Standard for Ethernet and, although there are some differences including different use of a length/type field, the two Standards are largely interchangeable and can be considered equivalent as far as this invention is concerned. The term "CSMA/CD" is used herein to refer generically to this technology. Using CSMA/CD, packets of data are communicated in frames that are generally referred to as Ethernet frames. This term is also used herein, regardless of whether the frames comply with the 802.3 Standard or the Ethernet Standard (i.e. regardless of the value contained in the length/type field of the frame).

The OSI (Open Systems Interconnection) reference model established by the ISO defines packetized communications protocols in seven layers, of which Layer 1 is the physical layer which is concerned with the physical interfaces between devices and the communications medium, and Layer 2 is the data link layer which is concerned with sending and receiving blocks of data together with information for example for synchronization and error and flow control. For LANs, the data link layer is generally considered as comprising two sub-layers, referred to as the LLC (logical link control) layer and the MAC (medium access control) layer. The LLC layer (Layer 2) is addressed by IEEE Standard 802.2. The CSMA/CD Standards address communications at the MAC and physical layers (Layers 2 and 1).

A particularly convenient and popular physical medium for LAN communications is twisted pair wiring as is commonly used for telephone communications. Such wiring typically consists of 0.4 mm to 0.6 mm diameter (26 AWG to 22 AWG) unshielded wires twisted together in pairs in a multipair cable. For example, one of the options for the physical layer documented for CSMA/CD is referred to as 10BASE-T and provides baseband communications at a data rate of 10 Mb/s over twisted pair wiring. The performance specifications are generally met by up to 100 m (meters) of 0.5 mm telephone twisted pair wire without the use of a repeater. Longer wiring lengths are permitted as long as the performance specifications, in particular a maximum delay, are met.

Accordingly, devices that are located relatively close to one another, for example within a building, can be relatively easily connected in a LAN using twisted pair wiring. For CSMA/CD communications via the LAN and for access to the Network, each device is easily equipped with an Ethernet interface card, which is connected via a respective twisted pair of wires to a repeater or CSMA/CD hub, and with TCP/IP (Transmission Control Protocol/Internet Protocol) software that handles the packetized communications at Layers 3 and 4 of the OSI model (Network and Transport Layers, respectively).

Increasingly, access to the Network is required from devices that are relatively distant from existing Network facilities. For example, such devices may be located within residences and small businesses, and they may be isolated computers or they may be connected in a LAN that is not connected to the rest of the Network. Such devices may for example comprise general-purpose computers or specific-purpose devices such as a Network browser, game machine, and/or entertainment device, and may also comprise related and/or ancillary equipment such as workstations, printers, scanners, bridges, routers, etc. that it may be desired to connect to the Network. The generic term "terminal device" and its abbreviation "TD" is used below to embrace all such devices.

It is known to provide for access to the Network from a relatively distant terminal device, or TD, via a communications path between a router on the Network and the distant TD, the communications path typically being constituted by a telephone line.

A simple form of such a communications path is a serial link comprising modem communications via a conventional two-wire telephone line. At Layers 1 and 2 of the OSI model the CSMA/CD communication, which can not be used on the serial link because of its length and characteristics, is replaced for the communication with each distant TD by modem communications via the respective telephone line and a point-to-point protocol, such as PPP (Point to Point Protocol) or SLIP (Serial Link Internet Protocol). Currently, modem communications generally provide a maximum data rate of 28.8 kb/s, and may typically operate in practice at lower, fall-back, data rates such as 19.2 or 14.4 kb/s. Such data rates are increasingly insufficient to meet demands imposed on communications for Network access, in particular for rapid downloading of relatively large amounts of data, e.g. for graphics. In addition, use of such modem communications prevents simultaneous use of the telephone line for telephone communications. Furthermore, such a communications path is set up as a dialled connection via the public switched telephone network (PSTN), which involves the inconvenience to the distant TD user of having to establish the dialled connection and the disadvantage of long connection times via the PSTN.

An alternative form of telephone communications path comprises an ISDN (Integrated Services Digital Network) telephone line. This provides two 64 kb/s B-channels each of which can be used for carrying voice communications or data A TD can be connected to the ISDN line via a terminal adapter, which can thereby provide a total bit rate of 128 kb/s for data on both B-channels, or 64 kb/s for data on one B-channel simultaneously with digital telephone voice communications on the other B-channel. While this provides a significant increase in data rate compared with using a conventional two-wire telephone line, it requires an ISDN telephone line which, in the relatively limited areas in which it is available, involves additional cost, and the connection still has the disadvantage of being a dialled connection via the telephone network. In addition, a terminal adapter is generally more costly than a modem. Furthermore, even data rates of 64 kb/s or 128 kb/s are likely to be increasingly insufficient with evolution of the Network.

Higher speed telecommunications lines may be available for lease to provide high data rate communications, but these are not economical for TDs in residences and most small businesses. Cable modems have also been proposed for providing Network access via coaxial (coax) or hybrid fiber-coax (HFC) cable television distribution networks that provide bidirectional communications. While such proposals offer the possibility of high data rates, they are also limited to their own serving areas and are likely to involve relatively high costs for both the modem equipment and the ongoing use of the service.

Accordingly, there is an increasing need to facilitate access from terminal devices to the Network at relatively low cost both for equipment and ongoing service, that is not restricted to particular areas, that provides for high data rates, and that desirably does not preempt telephone communications or require long connection times via the PSTN. An object of this invention is to address this need.

SUMMARY OF THE INVENTION

According to one aspect, this invention provides a method of communicating information packets to and from a CSMA/CD (Carrier Sense Multiple Access with Collision Detection) path via a bidirectional communications path, comprising the steps of coupling a first end of the communications path to a first modem; communicating information packets between the CSMA/CD path and the first modem via a CSMA/CD interface: coupling a second end of the communications path to a second modem; communicating information packets and control information, for controlling operation of the second modem, from the first modem to the second modem via the communications path; and communicating information packets from the second modem to the first modem via the communications path under control of the control information; the control information providing half duplex communications on the bidirectional communications path.

The half duplex communications, which can alternatively be considered as time division duplex or time compression multiplex communications, avoid collisions or interference between information packets communicated in the two directions of communication on the communications path by ensuring that the communications in the two directions take place at different times.

Preferably each step of communicating information packets comprises enveloping them in information frames which also comprise error check fields for error checking of at least the enveloped information packets. Information relating to

operation of the modems, such as the control information from the first modem to the second modem and response information from the second modem to the first modem, can be included in at least some of the information frames and/or in further frames which comprise this information and an error check field for error checking of at least this information.

Preferably each information packet communicated between the modems via the communications path comprises at least address, length, and data fields of an Ethernet frame communicated via the CSMA/CD path, it desirably also comprises a frame check sequence of the respective Ethernet frame, and may further comprise a preamble and start frame delimiter of an Ethernet frame.

Advantageously, the communications path comprises a two-wire telephone subscriber line and the modems communicate said information packets via the line at frequencies greater than telephone signal frequencies, the method further comprising the steps of communicating telephone signals via the line and, at each end of the line, combining telephone signals and information packets to be communicated via the line, and separating telephone signals and information packets communicated via the line, using a diplexer.

The method can further comprise the step of multiplexing signals of the first modem for communicating information packets between the first modem and a plurality of second modems.

The method can further comprise the steps of monitoring errors in communicating said information packets between the first and second modems via the communications path, and determining operations of the first and second modems in dependence upon monitored errors. The step of determining operations of the moderns in dependence upon monitored errors can comprise varying a signal bandwidth and/or a modulation method of the modems. This enables an optimum rate to be achieved for communicating information packets via any particular two-wire line.

The method can further comprise the step of communicating information packets between the second modem and a second CSMA/CD path via a second CSMA/CD interface.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be further understood from the following description with reference to the accompanying drawings, in which:

FIG. **1** schematically illustrates a known Network access arrangement;

FIG. **2** illustrates the known format of an Ethernet frame;

FIG. **3** schematically illustrates a Network access arrangement in accordance with an embodiment of this invention;

FIG. **4** schematically illustrates a Network access arrangement providing for simultaneous telephone communications, in accordance with another embodiment of this invention;

FIG. **5** schematically illustrates a diplexer used in the arrangement of FIG. **4**;

FIG. **6** shows a graph illustrating frequency characteristics related to the arrangement of FIG. **4**;

FIG. **7** schematically illustrates a master modem provided in the Network access arrangements of FIGS. **3** and **4**;

FIG. **8** schematically illustrates a slave modem provided in the Network access arrangements of FIGS. **3** and **4**;

FIGS. **9** to **11** illustrate frame formats that can be used in Network access arrangements in accordance with embodiments of the invention;

FIGS. **12** to **14** are flow charts with reference to which operation of the master and slave modems is described; and

FIG. **15**, which is on the same sheet as FIG. **8**, schematically illustrates a combined unit which replaces a slave modem and Ethernet interface provided in the arrangement of FIG. **3**.

DETAILED DESCRIPTION

FIG. **1** illustrates elements of a known arrangement for access from a subscriber to the Network **10** via a conventional two-wire telephone line **12**. Subscriber equipment includes a terminal device (TD) **14** which for example is constituted by a personal computer (PC), and a modem **16** connected to the line **12** and for example providing a maximum data rate of 28.8 kb/s. Although shown separately from the TD **14**, the modem **16** can instead be incorporated therein. The modern **16** communicates with a modem in a pool of dial-up modems **18** with a dialled connection which is established in well-known manner via the PSTN **20** to which the telephone line **12** is connected. The modems in the modem pool **18** are connected via an Ethernet interface (ENET I/F) **22** to a router **24** which is connected to the Network **10** and hence can be considered to be a part of the Network, the Network **10** generally being considered to include all of the terminal devices connected to it.

An upper part of FIG. **1** illustrates protocols in accordance with which the arrangement operates. TCP/IP operates at OSI Layers 3 and 4 end-to-end throughout the entire Network and access arrangement, with TCP/IP software running on the TD **14**. At the MAC layer of OSI Layer 2, communications in the access arrangement between the Ethernet interface **22** and the TD **14** operate in accordance with a point-to-point protocol such as PPP or SLIP, and communications between the Ethernet interface **22** and the Network **10**, and within the Network **10**, comprise Ethernet frames as described below with reference to FIG. **2**. These frames can be carried in a wide variety of forms and via various physical media, for example as the Ethernet frames themselves on a CSMA/CD LAN, in ATM (asynchronous transfer mode) cells, in SONET (synchronous optical network) formats, and so on. For communications between the Network **10** and the TD **14**, the router **24** converts between the Ethernet frames of the Network and the serial communications on the line **12** between the modems **16** and **18**.

A generally similar arrangement to that of FIG. **1** is provided in the event that the telephone line is an ISDN line, except that the modem **16** is replaced by an ISDN terminal adapter and communications on the line are digital at a rate that can be 64 or 128 kb/s.

FIG. **2** illustrates the Ethernet frame at the MAC layer. It consists of, in order, a preamble field of 7 bytes or octets (8 bits) of alternating 1s and 0s starting with a 1; a start frame delimiter (SFD) field of 1 byte having the sequence 10101011; a destination address field of 6 bytes: a source address field of 6 bytes: a length or type field of 2 bytes described further below; a data field of 46 to 1500 bytes, and a frame check sequence (FCS) field of 4 bytes or octets constituted by a CRC (cyclic redundancy check) of the data packet constituted by the address, length or type, and data fields. Data of less than 46 bytes in a frame is padded to the minimum data field size of 46 bytes. In accordance with the 802.3 Standard, the length or type field represents the length of data in the data field up to the maximum of 1500 bytes. In accordance with the Ethernet Standard, the length or type field is a value greater than 1500 that represents the type of data packet, and IP data packets are identified by one specific type value in this field. Thus the two Standards are different but inter-operable in this respect. It follows from this format that each frame comprises a data packet of from 60 to 1514 bytes, together with overhead (preamble, SFD, and FCS fields) of 12 bytes.

In accordance with the CSMA/CD Standards, the bits of each Ethernet frame are communicated using Manchester coding (a 1 bit is encoded as a 01 sequence, and a 0 bit is encoded as a 10 sequence, in each case with a transition in the middle of the bit period) at a predetermined data rate which is typically 10 Mb/s. Any terminal device connected to a CSMA/CD LAN can transmit a frame to the LAN (Multiple Access) in accordance with a contention scheme which is summarized by the following steps:

1. Monitor the LAN (Carrier Sense).
2. When the LAN is idle, transmit.
3. While transmitting, monitor the LAN for a collision (Collision Detection) by comparing transmitted bits with what is received from the LAN.
4. When a collision is detected, continue transmitting for a short period so that all TDs on the LAN detect the collision (this is referred to as jamming). Wait a random period of time determined by a binary exponential back-off algorithm, then return to step 1 for retransmission.

The minimum and maximum Ethernet frame size, predetermined data rate, and characteristics and lengths of segments of the LAN are inter-related in a manner that ensures effective operation of this contention scheme. For a 10BASE-T LAN using twisted pair wiring, as explained in the background of the invention this results in a maximum segment length of the order of 100 meters.

The two-wire telephone line **12** in the arrangement of FIG. **1** is constituted by twisted pair wiring, but has a length which is invariably much greater than 100 meters. Typically the length may be a maximum of about 5500 meters, with an average length for telephone lines in North America of the order of 1700 meters. These lengths are much greater than the approximate 100 meter maximum for a 10BASE-T LAN, and propagation delays make it impossible for the contention scheme outlined above to operate over such distances of twisted pair wiring. Even if this were not the case, signal attenuation over these distances of twisted pair wiring would make it very difficult to provide any reliable detection of collisions. Accordingly, it is not practical to use CSMA/CD on the telephone line **12**. Instead, the serial link point-to-point protocols are used in conjunction with the modems **16** and **18** as discussed above to provide Network access, with the data rate and other limitations discussed in the background of the invention.

FIG. **3** illustrates a Network access arrangement in accordance with an embodiment of this invention which is described first below, and also illustrates variations of this which are described subsequently below.

In FIG. **3**, a TD **14** of a subscriber is again connected to the Network **10** via a two-wire telephone subscriber line **12** which in this arrangement, as in the arrangement of FIG. **1**, is not being used for telephone communications. The TD **14** in this arrangement is connected to the line **12** via an Ethernet interface (ENET I/F) **30** and a modem **32**. The interface **30** is a conventional Ethernet interface which, although shown separately from the TD **14** in FIG. **3**, can be conveniently incorporated into the TD **14** either on a plug-in card or as a permanent part of the TD **14**. The interface **30** is the same as would be provided for connecting the TD **14** directly to a CSMA/CD LAN. The modem **32** has a form for

example as described in detail below with reference to FIG. **8**, and has an Ethernet interface that is connected to the interface **30**, and a two-wire line interface that is connected to the line **12**. Conveniently, the connection between the Ethernet interface **30** and the modem **32** is a 10BASE-T connection using twisted pair wiring. The modem **32** is referred to below as a slave modem as explained further below. The Ethernet interface **30** provides a Network address for the TD **14** as is well known. Similarly, the Ethernet interface within the modem **32** provides this with a Network address. Although the slave modem **32** is shown separately from the interface **30** and the TD **14**, the modem **32** can be physically combined with the Ethernet interface **30** for example as described below with reference to FIG. **15**, and can be incorporated into the TD **14**.

At its other end, for example at a PSTN central office (CO) or remote terminal (RT), the two-wire telephone line **12** is connected to a modem **34** which is referred to as a master modem and an example of which is described below with reference to FIG. **7**. The modem **34** also has a 10BASE-T Ethernet interface which provides the master modem with a Network address. This interface is connected via twisted pair wiring **36**, an Ethernet switch **38**, and a router **40** to the rest of the Network **10** in known manner. As is well known, functions of the switch **38** and router **40** can be combined in a single device referred to as a brouter.

An upper part of FIG. **3** illustrates in a similar manner to FIG. **1**, protocols in accordance with which the Network access arrangement operates. As in the arrangement of FIG. **1**, TCP/IP operates at OSI Layers 3 and 4 end-to-end throughout the entire Network and access arrangement, with TCP/IP software running on the TD **14**. At the MAC layer, communications within and between the Network **10**, router **40**, switch **38**, and master modem **34** comprise Ethernet frames as described above. Similarly, communications between the slave modem **32** and the Ethernet interface **30** comprise Ethernet frames as described above, and the TD **14** operates in exactly the same known manner as it would if the interface **30** were connected directly to a LAN.

Communications between the master modem **34** and the slave modem **32** are carried out in accordance with a new point-to-point protocol which uses collision avoidance to communicate Ethernet frames between the modems. This protocol is described below and for convenience is referred to herein as ECAP (Ethernet frame Collision Avoidance Protocol). It is observed that this protocol operates only between the modems **32** and **34**, and hence need not be known to, and does not change the operation of, the TD **14** or the rest of the Network **10**. The protocol and modems simply serve to replace a direct (short-distance) connection between the interface **30** and the twisted pair wiring **36** by a remote connection via the (much greater distance) two-wire line **12**. Thus although as described here the line **12** is a telephone subscriber line, it can be appreciated that the same arrangement of master and slave modems operating in accordance with this new protocol can be used to communicate Ethernet frames via any twisted pair wiring which is too long to permit conventional 10BASE-T or similar LAN interconnections.

FIG. **3** also illustrates a management device **42**, for example a computer, coupled to the Ethernet switch **38** for providing operations, administration, management, test, and other functions relating to the communications in known manner. In order to provide communications via multiple lines **12** to multiple subscribers, preferably the master modem **34** contains multiplexing functions as described below with reference to FIG. **7**, and other master modems, one of which is illustrated in FIG. **3** and referenced **34'**, are connected to the switch **38** similarly to the modem **34**.

At the subscriber, one or more further arrangements of a slave modem **32'**, Ethernet interface **30'**, and TD **14'** can be similarly connected to the same two-wire line **12** as shown by a dashed line connection **44**. Alternatively (or in addition), and generally more desirably, as shown by a dashed line connection **46** the 10BASE-T connection of the slave modem **32** can be connected to a bridge **48** of known form, to which a plurality of TDs **14"** can be connected via their respective Ethernet interfaces (E I/Fs) in known manner to provide a subscriber LAN. These arrangements can be extended as desired in known manner.

It can be seen from the above description that embodiments of the invention are centered on the arrangement and functioning of the modems **32** and **34**. Before describing embodiments of these in detail, a further Network access arrangement is described below with reference to FIG. **4**. This further arrangement illustrates that the communications on each line **12** can comprise not only the data communications for the Network as described herein but also conventional telephone communications.

Referring to FIG. **4**, this illustrates the master and slave modems **34** and **32** respectively, with 10BASE-T interfaces to twisted pair wiring **36** and **46** respectively as described above, coupled via a two-wire subscriber line **12** which also serves for conventional telephone connections between a subscriber telephone **51** and a telephone CO or RT **50** connected to the PSTN. To this end, a passive diplexer **52** is provided at each end of the two-wire line **12**, the two diplexers **52** conveniently having the same form and being for example as described below with reference to FIG. **5**. Thus at a head end of the line **12** the CO or RT **50** and the master modem **34** are connected via a diplexer **52** to the line **12**, and at a subscriber end of the line **12** the subscriber telephone **51** and the slave modem **32** are connected to the line **12** via a diplexer **52**. As also shown in FIG. **4**, the master modem **34** can be multiplexed for other telephone subscriber lines **12'** to which it is similarly connected via respective diplexers **52'**. It can be appreciated that diplexers can be similarly provided in the arrangement of FIG. **3** to permit simultaneous telephone and Network communications.

FIG. **5** illustrates a simple form of the diplexer **52**, which comprises a d.c. and low pass filter (LPF) **54** between a two-wire connection to the line **12** and a two-wire connection to the telephone **51** or CO or RT **50**, and a d.c. isolator and high pass filter (HPF) **56** between the two-wire connection to the line **12** and a two-wire connection to the modem **32** or **34**. As illustrated in FIG. **5**, the LPF **54** can comprise one or more balanced filter sections comprising series inductors (which pass the telephone loop current) and shunt capacitors, and the HPF **56** can comprise two series capacitors having a capacitance such that they do not represent a significant load to the line **12**. More complicated forms of diplexer **52** can be provided as desired.

The graph in FIG. **6** illustrates the low frequency spectrum **60** of analog telephony signals, and two high frequency spectra **62** and **64** for Network communications. A desirable response **66** for the LPF **54** of the diplexer **52** separates the low frequency telephony signals on the two-wire line **12** from the Network communications signals on the same line **12**. It can be seen from this illustration that the telephony and Network communications signals occupy substantially different frequency bands and hence are easily separated by the diplexers **52**.

In FIG. **6**, the spectra **62** and **64** relate to two different signal bandwidths which can be used for the Network

communications. For example, the relatively wide bandwidth spectrum **62** can correspond to a modulation method with a symbol or clock rate of 3 MHz, and the relatively narrower bandwidth spectrum **64** can correspond to a modulation method with a symbol or clock rate of 300 kHz. Other signal bandwidths, not shown, can be similarly provided. The use of different bandwidths and modulation methods is described further below.

FIG. **7** illustrates a form of the master modem **34**, including optional but desirable multiplexing for a plurality of two-wire lines. The master modem includes an Ethernet interface **70** of known form providing a 10BASE-T connection to the twisted pair wiring **36** and providing (for example from a read-only memory within the interface **70**) a Network address for the master modem. The interface **70** is connected to a control unit **72** of the master modem, to the input of a FIFO (first in, first out) buffer **74** for buffering downstream Ethernet frames supplied from the Network via the wiring **36** and the interface **70**, and to the output of a FIFO buffer **76** for supplying upstream Ethernet frames via the interface **70** and the wiring **36** to the Network. An output of the buffer **74** is coupled via a modulator **78** and a downstream demultiplexer **80** (constituted by switches) to a respective one of the multiplexed two-wire lines **12** via a respective isolating transformer (TR) **82**, the output of the modulator **78** providing a matched termination for the line **12**. An upstream multiplexer **84** (constituted by switches) has inputs also coupled to the lines **12** via the transformers **82**, and has an output coupled via a high pass filter (HPF) **86** which provides a matched termination for the respective line **12** to which it is connected via the multiplexer **84**. An output of the HPF **86** is connected to an input of a demodulator **88** having an output connected to an input of the buffer **76**. The transformers **82** can also provide a balun function between the balanced lines **12** and the demultiplexer **80** and multiplexer **84**.

The demultiplexer **80** and multiplexer **84** are addressed by the control unit **72** via address lines **90** and **92** respectively to provide downstream frames to and to receive upstream frames from respective ones of the lines **12**. The addresses on the lines **90** and **92** are generally different for efficient data flow in the downstream and upstream directions, but they can be the same for example for loopback testing of a slave modem **32**. To provide different logical buffers for frames in the buffers **74** and **76** associated with the respective lines **12**, the buffers **74** and **76** are also addressed via the address lines **90** and **92** respectively. A store **94** is also addressed with the upstream multiplexer address on the lines **92** to provide to the demodulator **88** stored data, such as echo coefficients and signal amplitude level, relating to the respective line **12** to facilitate fast acquisition (recognition of the preamble of a frame) by the demodulator **88**. A store **95** is similarly addressed with the downstream demultiplexer address on the lines **90** to provide to the modulator **78** stored data to determine a signal transmission level and possibly frequency characteristics for the respective line **12**. Information for the stores **94** and **95** is determined, and the stores are updated, by the control unit **72** in known manner. Control lines **96** and **98** are provided between the control unit **72** and the modulator **78** and demodulator **88** respectively for communicating control information.

FIG. **8** illustrates a complementary form of a slave modem **32**. The slave modem includes an Ethernet interface **100** of known form providing a 10BASE-T connection to the twisted pair wiring **46** and providing (for example from a read-only memory within the interface **100**) a Network address for the slave modem. The interface **100** is connected to a control unit **102** of the slave modem, to the input of a FIFO buffer **104** for buffering upstream Ethernet frames supplied from the TD via the wiring **46** and the interface **100**, and to the output of a FIFO buffer **106** for supplying downstream Ethernet frames via the interface **100** and the wiring **46** to the TD. An output of the buffer **104** is coupled via a modulator **108**, a current generator **110**, and an isolating transformer **112** to the two-wire line **12**. The transformer **112**, which can also provide a balun function for the balanced line **12**, is also coupled via a high pass filter **114** and a demodulator **116** to an input of the buffer **106**. The current generator **110** provides a high output impedance to avoid loading of the line **12**, and the HPF **114** provides a matched termination of the line **12**, so that these can both be connected to the line **12** without any switching. This enables loopback testing of the line **12** from the control unit **102**. Control lines are provided between the control unit **102** and the buffers **104** and **106**, modulator **108**, and demodulator **116**.

It can be appreciated that, apart from the functions related to the multiplexing and switching for a plurality of lines **12**, and the operation of the modems as described below, the master modem **34** and the slave modem **32** are similar, and the arrangement of the slave modem shown in FIG. **8** could also be used as a master modem for a single line **12**.

In each of the modems **32** and **34** the modulator, demodulator, and related functions are conveniently implemented in known manner using one or more DSPs (digital signal processors) with analog-digital conversion in known manner. DSPs can be conveniently controlled to provide an arbitrary number of different signal bandwidths for example as illustrated by the spectra **62** and **64** in FIG. **6**. Conveniently the DSPs provide a common lower frequency limit of about 10 kHz for all of the signal bandwidths as shown in FIG. **6**, with the different bandwidths being determined by the symbol or clock rate as described above. The particular modulation method that is used is relatively arbitrary, but conveniently the DSPs in the modems are programmed to select any of a plurality of modulation methods, for example 16QAM (quadrature amplitude modulation), QPSK (quadrature phase shift keying), and BPSK (binary phase shift keying), providing different numbers of bits per symbol. These particular methods and numbers are given only by way of example, and other modulation methods, such as VSB (vestigial sideband), carrierless amplitude-phase, and DMT (discrete multi-tone) modulation, may be used instead, numerous different numbers of bits per symbol may be used, and the signal bandwidths may be arbitrarily defined (e.g. with different low-frequency cutoffs) as desired.

The master and slave modems communicate Ethernet frames downstream (from the master modem **34** to the slave modem **32**) and upstream (from the slave modem **32** to the master modem **34**) in a manner described in detail below. Briefly, this communication involves half-duplex transmission using a collision avoidance protocol (ECAP) in which the master modem **34** has priority and control over the slave modem **32**. Thus the master modem **34** determines when to send information downstream via the line **12**, and informs the slave modem when it is permitted to send information upstream via the line **12**. To facilitate these communications, the information sent via the line **12** comprises not only the data packets of Ethernet frames for Network communications but also control packets downstream and response packets upstream between the master and slave modems. These packets are incorporated into ECAP frames examples of which are described below with reference to FIGS. **9** to **11**. The control units **72** and **102** in the master and slave

modems perform the necessary conversions between the Ethernet frames and ECAP data frames, and generate and respond to the ECAP control and response frames.

FIG. **9** illustrates an ECAP data frame which comprises overhead information O/H, followed by an Ethernet frame in exactly the same form as described above with reference to FIG. **2**, followed by a check sequence CHK. The O/H field for example consists of a few bytes comprising a preamble and start-of-frame (SOF) indication of a suitable form for the modulation method in use by the master and slave modems, possibly followed by other information such as an ECAP frame sequence number for frame identification in known manner (e.g. for identifying frames for acknowledgement or retransmission). The check sequence CHK conveniently comprises a CRC sequence which can be produced in exactly the same manner as the FCS field of the Ethernet frame, the CRC operating on all of the information in the ECAP frame following the SOF indication up to and including the FCS at the end of the Ethernet frame. Thus as shown in FIG. **9** the Ethernet fame is enveloped, intact and without any change, within the ECAP frame.

Alternatively, as illustrated in FIG. **10**, the preamble and SFD fields can be stripped from the Ethernet frame and only the remainder of the Ethernet frame (i.e. the data packet and FCS field) incorporated into the ECAP frame between the overhead field O/H and the check sequence CHK. In this case the preamble and SFD fields of the Ethernet frame are stripped for example by the control unit of whichever of the master and slave modems **34** and **32** is sending the frame, and is reinserted by the control unit of the receiving one of the modems **34** and **32** for forwarding the Ethernet frame to the respective Ethernet interface. This reduces slightly the amount of information to be transmitted via the line **12**. Further reductions are possible if for example the pad, used for increasing data packets of less than 46 bytes to the minimum data field size of an Ethernet frame, can also be identified, stripped prior to sending the remainder of the frame between the modems **34** and **32**, and reinserted at the receiving modem. However, it may be more desirable for the modems **34** and **32** always to communicate the entire data packet and FCS field of each Ethernet frame intact, to avoid risk of corrupting the Ethernet frame contents.

Thus whereas transmission of undersized frames is not possible in a CSMA/CD arrangement because of the nature of the contention scheme (they are generally interpreted as collisions), in this ECAP scheme collisions are avoided by the protocol between the master and slave modems so that short frames are not only permitted but can be desirable because they reduce the amount of information that must be communicated via the line **12**.

To this end, FIG. **11** illustrates an ECAP control frame comprising a control packet to be communicated from the master modem **34** to the slave modem **32**. The control frame comprises an initial overhead field O/H as described above, followed by a control packet described below, and the check field CHK providing a CRC sequence for all of the information in the ECAP frame following the SOF indication up to the end of the control packet. The control packet comprises destination and source address fields, a length/type field L/T, and a control field which is generally much shorter than the minimum 46 byte data field of an Ethernet frame and whose length is given by the contents of the field L/T. For such a control packet the destination and source addresses are the Network addresses of the slave modem **32** and the master modem **34**, respectively.

Conversely, an ECAP response frame can have the same form as the control frame shown in FIG. **1**, except that it contains a response field instead of the control field and the destination and source addresses are exchanged because the response frame is communicated from the slave modem **32** to the master modem **34**.

Other ECAP frame formats can alternatively be provided to suit particular situations; for example for convenience or simplicity the control and response frames can have a fixed size and can be the same size as a data frame containing a minimum-size data packet. In addition, although as described here by way of example the control frames are separate from the data frames, control information can instead be incorporated into the ECAP data frames, desirably keeping the enveloped Ethernet frame contents intact, for example as an additional part of the overhead field O/H or between the CRC fields FCS and CHK.

The following description of an example of the collision avoidance protocol, with reference to FIGS. **12** to **14**, assumes for simplicity and clarity that the master modem **34** typically sends a single data frame followed by a control frame downstream, and then waits for a response from the slave modem **32**, and that the slave modem waits for these downstream frames and then typically sends a response frame followed by a single data frame upstream. It also assumes for simplicity that there is only one slave modem **32** connected to the line **12**. Various modifications and extensions of this protocol, for example to accommodate multiple slave modems **32** connected to the same line **12**, can be contemplated and some variations are described later below.

FIG. **12** illustrates a downstream transmitting flow chart for the master modem **34**, and FIG. **13** illustrates an upstream receiving flow chart for the master modem **34**, the master modem **34** being assumed here simply to alternate between the transmitting and receiving states for communications with a single slave modem **32**. As already described, the master modem **34** can provide multiplexed operations for a plurality of slave modems, so that in practice the transmitting and receiving processes can take place simultaneously and independently in a multiplexed manner for a plurality of slave modems. FIG. **14** illustrates a downstream receiving and upstream transmitting flow chart for the slave modem **32**. The operations in the modems in each case take place under the control of the respective control unit **72** or **102**, and the master and slave modems differ in the manner in which these units operate as described below.

Referring to FIG. **12**, in the transmitting sequence of the master modem **34** its control unit **72** initially determines in a decision **120** whether the downstream buffer **74** (for the respective line **12** and slave modem **32**) is empty. If not, i.e. if there is at least one Ethernet frame to be sent from the buffer **74**, then at a block **121** the next frame to be sent downstream from the buffer **74** is transmitted in an ECAP data frame as described above. At a block **122** the control unit **72** then sends a control frame as described above, and sets a timer for a response from the slave unit. In the event that the buffer **74** is empty as determined in the decision **120**, then in a decision **123** the control unit **72** determines whether or not to send a control frame, if so proceeds to the block **122** to send a control frame, and if not returns to the start of the transmitting sequence. The decision **123** whether or not to send a control frame may depend upon various parameters which are monitored by the control unit **72**, such as the fill state of the upstream receiving buffer **76**, the state of the slave modem and the fill state of its upstream transmitting buffer **104**, and the time since the previous control frame was sent to the slave modem. The contents of the control frame can comprise, for example, a request (poll) for the slave modem to transmit a frame of data upstream, a request

for retransmission by the slave modem of a previous frame that has not been received correctly as determined by its check field CHK, control information such as operating parameters for the slave modem, and/or a request for status information, such as the fills of the buffers **104** and **106**, from the slave modem.

Referring now to FIG. **14**, at a block **140** the control unit **102** of the slave modem **32** initially waits for a frame to be received from the master modem **34**. This waiting, and the subsequent operation of the slave modem in response to a received frame and operation of the master modern, ensures that collisions on the line **12** are avoided by giving control of the ECAP frames on the line **12** entirely to the master modem **34**. In response to receipt of a downstream frame from the master modem **34**, the control unit **102** of the slave modem determines in a decision **141** from the field CHK whether the frame has been received properly and, if not, at a block **142** sets a status flag to request retransmission of the frame and returns to the wait block **140**. If the frame has been properly received the control unit **102** proceeds to a decision **143**.

In the decision **143** the control unit **102** determines whether or not the destination address in the received frame is the address of the slave modem, and hence whether the frame is a control frame or a data frame. If the frame is determined to be a data frame, then in a block **144** the control unit **102** sets a status flag for acknowledgement of the frame, and in a block **145** the data frame is stored in the buffer **106** and a return is made to the wait block **140**.

If in the decision **143** the frame is determined to be a control frame, then in a block **146** the control unit **102** generates and sends a response frame upstream to the master modem. The contents of the response frame depend on the nature of the received control frame and the status of the slave modem, but for example can include status information, an acknowledgement of the received data frame (based on the acknowledgement status flag), a request for retransmission of an incorrectly received frame (based on the retransmission status flag), and buffer fills of the buffers **104** and **106**. In a decision **147**, the control unit **102** then determines whether a data frame is to be sent upstream, i.e. whether the received downstream control frame included a retransmission request or a poll for an upstream data frame and such a data frame is available in the upstream transmission buffer **104**. If so, at a block **148** the control unit **102** sends the requested data frame from this buffer **104** upstream to the master modem. After the block **148**, or if no upstream frame is to be sent as determined in the decision **147**, a return is made to the wait block **140**.

Referring now to FIG. **13**, after the downstream transmitting sequence described above with reference to FIG. **12** the control unit **72** in the master modem **34** waits, as shown by a block **130**, for an upstream frame to be received or for the timer (set at block **122**) to time out. If an upstream frame is received, then in a decision **131** the control unit **72** determines from the field CHK whether the frame has been received properly and, if so, proceeds to a decision **132**. In the event that the timer times out in the block **130** or the frame is incorrectly received as determined in the decision **131**, then in a block **133** the control unit **72** updates a record of the communications status of the master modem with the slave modem. This status record contains various parameters of the communications such as those already discussed, for example the status of acknowledgements and retransmission requests, buffer fills, and operating parameters of the modems.

In the decision **132** the control unit determines, from the destination address of the received upstream frame and in accordance with its expectations based on the status of the communications, whether this is a response frame (i.e. the destination address is the address of the master modem) as expected first from the slave modem, or a data frame for which a poll or retransmission request has been sent to the slave modem as described above, or whether the frame does not have the expected form (e.g. it is a data frame when a response frame is expected). In the latter case the communications status is updated in the block **133**, and the control unit **72** proceeds in a manner dependent upon the updated status. For example, from the block **133** the control unit returns from the upstream receiving sequence of FIG. **13** to the downstream transmitting sequence of FIG. **12**, and can send a control frame requesting retransmission of an upstream frame for which there has been a timeout from the block **130**, a CRC error as determined in the decision **131**, or an unexpected frame as determined in the decision **132**.

On receipt of an expected response frame, in a block **134** the communications status is updated accordingly, and in dependence upon a decision **135** either a return is made to the block **130** for a data frame expected following the response frame (a data frame is expected if it has been requested from the slave modem and the response frame has not indicated that the upstream transmitting buffer **104** is empty; the timer for the block **130** can be reset as desired) or the receiving sequence ends if no subsequent data frame is expected. On receipt of an expected data frame as determined in the decision **132**, in a block **136** the control unit **72** sets a status flag for acknowledgement of the frame, and in a subsequent block **137** the received data frame is stored in the upstream receiving buffer **76** and the receiving sequence ends. As already described above, at the end of the upstream receiving sequence the control unit **72** of the master modem **34** returns to the start of the downstream transmitting sequence already described.

The collision avoidance protocol as described above provides for an approximate one-to-one ratio of downstream and upstream Ethernet frames, and gives priority to the master modem and the transmission of downstream frames. This is desirable because the modem arrangement has no control over the supply from the Network of Ethernet frames incoming to the buffer **74**, and it is desirable to avoid overflow of this buffer which would result in a loss of data frames. Such a data frame loss can be accommodated by the TCP/IP operating at Layers 3 and 4 of the OSI model, but this is preferably avoided.

The same principles apply for upstream Ethernet frames incoming to the buffer **104** from the TD **14**, but in this case overflow of the buffer **104** can be prevented by the Ethernet interface **100** of the slave modem **32**, under the control of the control unit **102** in the event that the buffer **104** is about to overflow, jamming the 10BASE-T connection on the wiring **46** by transmitting a dummy signal to it. As discussed in the introduction, jamming is a well-known process for ensuring that a collision detected at one device on a CSMA/CD LAN is also detected by all other devices on the LAN, but in this case the jamming is triggered differently, by the potential overflow of the buffer **104**. The jam or artificially created collision on the wiring **46** is detected by the TD **14** connected to this wiring, and the TD backs off for subsequent retransmission of the Ethernet frame in known manner. In this manner, a loss of upstream data frames due to overflow of the buffer **104** is avoided. The same situation can take place in the event that the wiring **46** is connected to the bridge **48** on a subscriber LAN as described with reference to FIG. **3**, but in this case either the bridge **48** must be a learning bridge to avoid passing to the slave modem **32** via

the wiring **46** subscriber LAN frames not intended for upstream transmission, or such a learning function must be incorporated into the slave modem itself, otherwise jamming of all frames on the subscriber LAN will occur when the buffer **104** is about to overflow.

To reduce the possibility of buffer overflow, especially of the buffer **74**, the collision avoidance protocol described above can provide dynamic variation of the ratio of the numbers of downstream and upstream frames, for example in dependence upon the fills of the buffers. The buffer fills are monitored as described above by the control unit **72**, either directly in the case of the master modem **34** or via status information in response frames from the slave modem **32**. If the fill of the buffer **74** is increasing, then the master modem can simply send a plurality of data frames downstream instead of each single data frame as described above with reference to FIG. **12**, before sending the control frame to poll the slave modem for an upstream data frame, thereby increasing the downstream to upstream data frame ratio. Conversely, if the buffer **74** is relatively empty and the buffer **104** is relatively full, the master modem can provide repeated polls for single upstream data frames without sending downstream data frames using the protocol exactly as described above, or more desirably the ECAP control frame poll can be arranged to indicate to the slave modem a number of data frames that it is requested to transmit upstream in response to particular polls, with the slave modem responding accordingly.

It can be appreciated from the description above that the collision avoidance protocol ensures that the modems **34** and **32** operate in a half-duplex manner for communications between them via the line **12**, with the total transmission capacity of the line being shared, preferably dynamically dependent upon buffer fills as described above, between the downstream and upstream directions of transmission. The protocol can be refined, from its basic form as described above, in various ways to maximize the efficiency with which the total transmission capacity is used. For example, such refinements can include provisions for sending multiple data frames successively in either direction as described above, concatenating or merging control and/or data frames sent in the same direction, and advancing the timing of downstream frame transmission from the master modem in view of the loop delay on the line **12** (which can be measured in known manner by the master modem) and the knowledge in the master modem control unit **72** of what upstream frames are expected from the slave modem.

This total transmission capacity on the line **12** can also be varied dynamically by the master modem **34** in dependence upon monitored operating conditions, as explained further below.

As described above, the modulation and demodulation functions in the master and slave modems are desirably implemented using DSPs. A clock rate of the DSPs can be changed to vary the signal bandwidth as shown by the two different spectra **62** and **64** in FIG. **6**. A high clock rate provides a corresponding large bandwidth, for example as shown by the spectrum **62** in FIG. **6**, providing a high symbol transmission rate on the line **12** between the modems **34** and **32**. However, this involves greater susceptibility to noise (a large noise bandwidth) and greater signal attenuation (which is dependent on frequency). Conversely, a lower clock rate provides a smaller bandwidth, for example as shown by the spectrum **64** in FIG. **6**, providing a lower symbol transmission rate on the line **12** with less susceptibility to noise and less signal attenuation. Considered generally, higher symbol rates on the line **12** produce greater total transmission capacity and greater error rates, resulting in frames having to be retransmitted.

As also described above, the control unit **72** in the master modem **34** determines from the check field CHK of each received upstream frame whether the frame has been received correctly, and can monitor a proportion of correct upstream frames received. The control unit **72** can similarly monitor a proportion of correct downstream frames received by the slave modem **32** from information similarly available in the control unit **102** of the slave modem and communicated to the control unit **72** via the response frames. From such ongoing monitoring, the control unit **72** can determine dynamically whether the clock rate in current use for the DSPs is appropriate or should desirably be increased to increase the total transmission capacity on the line **12** or decreased to decrease the proportion of frames received in error. This can be determined either independently or in common for the upstream and downstream directions of transmission.

For example, if the control unit determines that a high proportion, more than an upper threshold value of for example 95 to 99%, of frames are received correctly, then it can decide to increase the DSP clock rate and hence the total transmission capacity. To this end it generates a control frame which is sent from the master modem to the slave modem instructing the slave modem to adopt a new, higher, clock rate for future frames, the slave modem responds accordingly, and the master modem switches its own clock rate. Conversely, if the control unit determines that a low proportion, less than a lower threshold value of for example 50 to 75%, of frames are received correctly, then it can decide to decrease the DSP clock rate to reduce errors. To this end it generates a control frame which is sent from the master modem to the slave modem instructing the slave modem to adopt a new, lower, clock rate for future frames, the slave modem responds accordingly, and the master modem switches its own clock rate. It can be appreciated that the threshold levels can be determined to provide a desired hysteresis for changing the clock rate, and that they may be adaptively adjusted by the control unit **72** in dependence upon the results of previous changes in clock rate.

The total transmission capacity is determined not only by the symbol transmission rate on the line **12** but also by the number of bits per symbol, and hence by the modulation method that is used. As described above, the modem DSPs can provide any of a plurality of modulation methods, such as 16QAM, QPSK, and BPSK providing respectively 4 bits, 2 bits, and 1 bit per transmitted symbol. In a similar manner to that described above for dynamically varying the symbol transmission rate, the control unit **72** can also or instead dynamically vary the modulation method. A determination as to whether to change the symbol transmission rate and/or the modulation method can be made by the control unit **72** in dependence upon various parameters such as the current symbol transmission rate and modulation method, a history of these operating parameters, the error rate, and monitored characteristics of the line **12** such as delay, signal levels, and echo parameters.

In any event, the dynamic variations discussed above enable the control unit **72** in the master modem **34** to determine and use, at any particular time for any particular line **12** to which it is connected, a clock rate and modulation method to provide an optimal total transmission capacity on that line. It can be appreciated that this optimal capacity may well include a certain proportion of frames that are in error and must be retransmitted, and that this is accommodated by the collision avoidance protocol as already described above.

The total transmission capacity can vary over an extremely wide range. For example, for a short line **12** and under good conditions, the modulation method may be 16QAM and the clock rate 3 MHz to provide a total transmission capacity of the order of the 10BASE-T bit rate of 10 Mb/s. Conversely, for a long line **12** (it is observed here that the line **12** must be unloaded to permit communication of signals at frequencies above the voice-band) and in poor conditions (e.g. in the presence of noise and crosstalk) the modulation method may be BPSK and the clock rate may be reduced to for example 30 kHz, thereby providing a total transmission capacity of about 25 kb/s (at for example 0.85 bits per Hertz to allow for excess bandwidth of the modem filters). However, it is noted that even this total transmission capacity is commensurate with the maximum bit rates of dial-up modems currently used to provide Network connections via conventional two-wire telephone lines. In practice, the total transmission capacity provided will be between these extremes, and will generally be substantially more than can be provided by currently used dial-up modems or on ISDN telephone lines.

It is also noted that the master modem **34** can be arranged to fall back to known modem communications methods in the event that it does not receive any ECAP response frames from a slave modem, so that the same master modem can operate alternatively with slave modems as described above or with conventional modems.

In use of the network access arrangement and protocol as described above, the master and slave modems and the line **12** simply serve to communicate Ethernet frames in both directions transparently between the wiring **36** and **46**. Accordingly, the subscriber is provided with a Network connection without any dialling process, and hence without involving a telephone connection via the PSTN, in the same way (as seen by the Network and by the subscriber) as if the wiring **36** and **46** were directly interconnected. As described above, this Network connection is established in a manner that is dynamically variable to provide an optimum total transmission capacity, which can be shared in a dynamically variable and optimized ratio of upstream to downstream data frames, for any prevailing conditions such as the characteristics of the line **12** and noise and crosstalk levels. For short lines **12**, the total transmission capacity is comparable with the bit rate of 10BASE-T LANS, so that there is no inherent deterioration of performance for communication of Ethernet frames. In addition, it is observed that because the frames on the line **12** are communicated in burst mode, there is statistically less energy on the line than would be the case for continuous data transmission on the same line, so that crosstalk with other lines in the same cable is reduced. Furthermore, the same line **12** can simultaneously carry conventional telephone signals, so that provision of the network access arrangement to a telephone subscriber does not necessitate the provision of an additional or separate telephone line.

Thus the use of the network access arrangement from a TD **14** is substantially the same as if the TD **14** were connected directly via an Ethernet interface to the Ethernet switch **38**. The TD **14** runs conventional software which, for initial access to the Network, in known manner sends information packets in Ethernet frames upstream, these packets containing for example the Network address of the management device **42** as the destination address and the Network address of the TD **14** as the source address. The packets are routed via the Ethernet switch **38** in known manner to the device **42**, and the switch **38** stores the address of the TD **14** for subsequent direction of Ethernet frames addressed to this address to this TD. In known manner, the device **42** either recognizes the source address of the TD **14** and provides a welcome message, or does not recognize it and initiates a registration process, and communications continue in known manner except that they take place via the modems **34** and **32** and line **12** instead of via a direct connection as is known.

In the embodiments described in detail above and as illustrated in FIG. **3** the slave modem **32** is separate from the Ethernet interface **30** connected to the TD **14** and includes its own Ethernet interface and Network address. While this is convenient in the case that the slave modem is connected to a subscriber LAN via the wiring **46**, it can be superfluous or undesirable in the event that the slave modem **32** is connected to only a single TD **14**, especially if the slave modem **32** and Ethernet interface **30** are merged together into a combined unit that may be incorporated into the TD **14** as would be desirable for example for an entertainment device. Even in the case of a subscriber LAN, the bridge **48** can be considered as a terminal device in which the slave modem **32** could be incorporated.

It can be seen, therefore, that the manner in which the slave modem **32** is ultimately connected to the TD **14** is relatively arbitrary as far as this invention is concerned, it only being necessary that the information be converted or translated between the Ethernet frames to and from the buffers **104** and **106** of the slave modem and whatever form is required for the connection to the TD **14** (for example, a PCM/CIA interface of known form), and that a Network address identify the TD, translator, and/or slave modem. Desirably, the slave modem **32** and the Ethernet interface **30** are merged into a combined unit, which can have a form for example as illustrated in FIG. **15**.

Referring to FIG. **15**, the combined unit has a similar form and operation to the slave modem **32** as described above with reference to FIG. **8**, and the same reference numerals are used to denote similar parts, except that the Ethernet interface **100** and wiring **46** of the slave modem of FIG. **8**, as well as the Ethernet interface **30** of FIG. **3**, are replaced by a data translator **150**. The translator **150** has an interface **152** to the control unit **102** and buffers **104** and **106**, and an interface **154** to the TD **14**, which are arranged and operate in the same manner as the corresponding parts of the known Ethernet interfaces **100** and **30** discussed above. Between these interfaces **152** and **154**, the unit **150** includes a minimized subset of the known circuits and functions of the Ethernet interfaces **100** and **30** necessary to translate data between the TD interface **154** and the Ethernet frame buffers **104** and **106**, and to provide a single Network address. This avoids the disadvantage of needing two Network addresses for the slave modem **32** and the Ethernet interface **30** respectively as in the embodiments of the invention described above, but makes it necessary to distinguish between ECAP control frames for the control unit **102** and ECAP data frames enveloping Ethernet frames containing data for the TD **14**.

Where the control frames and data frames are separate ECAP frames, this distinction can conveniently be provided by using the L/T field of the Ethernet frame. For an ECAP control frame, the L/T field can contain a pre-assigned (and otherwise unused) type having a value greater than the maximum value of 1500 for an Ethernet fame, which is recognized by the control unit **102** so that the control frame is not forwarded to the translator **150**. Alternatively, or in addition, as described above ECAP control information can be appended to Ethernet frames, for example in the overhead field O/H or between the FCS field of the enveloped Ethernet

frame and the check field CHK of the ECAP frame. In either case the control information can be of a fixed size or it can include its own length field to indicate its size. The L/T field of the enveloped Ethernet frame is not changed, to avoid any risk of corrupting the Ethernet frame.

Although particular embodiments of the invention and various modifications have been described in detail, it should be appreciated that numerous other modifications, variations, and adaptations may be made without departing from the scope of the invention as defined in the claims.

What is claimed is:

1. A method of communicating information packets to and from a CSMA/CD (Carrier Sense multiple Access with Collision Detection) path via communication of information corresponding to the information packets over a bidirectional communications path, the method comprising the steps of:

coupling a first end of the bidirectional communications path to the CSMA/CD path via a first modem having a CSMA/CD interface coupled to the CSMA/CD path, wherein the first modem is coupled to the first end of the bidirectional communications path via a first end interface;

communicating the information packets between the CSMA/CD path and the first modem via a CSMA/CD interface;

coupling a second end of the bidirectional communications path to a second modem, wherein the second modem is coupled to the second end of the bidirectional communications path via a second end interface;

communicating information corresponding to the information packets between the first and second modems via the bidirectional communications path using half duplex communications controlled by the first modem, wherein each of the information packets comprises a MAC-layer packet grouping of data that is grouped to fit into one MAC-layer packet of CSMA/CD networks, and wherein the half duplex communications are half-duplex with respect to MAC-layer packet groupings of data;

communicating control information for controlling the half duplex communications via the bidirectional communications path from the first modem to the second modem; and

changing direction of flow on the bidirectional communications path for the information corresponding to the information packets, the direction of flow changing based at least upon completion of communication associated with conveying information corresponding to at least one MAC-layer packet grouping of data across at least one of the first end interface and the second end interface.

2. A method as claimed in claim **1**, wherein the step of communicating the information packets using half duplex communications further comprises the step of enveloping information corresponding to at least one of the information packets in at least one information frame, the at least one information frame further comprising at least one error check fields for error checking of at least the enveloped information corresponding to at least one of the information packets.

3. A method as claimed in claim **2**, and further comprising the step of communicating further frames between the first and second modems via the bidirectional communications path, each further frame comprising information relating to operation of the modems and an error check field for error checking of at least the information relating to operations of the modems.

4. A method as claimed in claim **1**, wherein information corresponding to one of the information packets communicated between the modems via the bidirectional communications path comprises at least address, length, and data fields of a corresponding Ethernet frame communicated via the CSMA/CD path.

5. A method as claimed in claim **1**, and further comprising the step of multiplexing signals of the first modem for communicating information corresponding to at least one of the information packets between the first modem and a plurality of second modems.

6. A method as claimed in claim **1**, wherein the bidirectional communications path comprises a two-wire line.

7. A method as claimed in claim **1**, and further comprising the steps of:

monitoring errors in communicating the information corresponding to the information packets between the first and second modems via the bidirectional communications path,

and determining operations of the first and second modems in dependence upon monitored errors.

8. A method as claimed in claim **7**, wherein the step of determining operations of the modems in dependence upon monitored errors comprises varying a signal bandwidth of the modems for communicating the information corresponding to the information packets via the bidirectional communications path.

9. A method as claimed in claim **7**, wherein the step of determining operations of the modems in dependence upon monitored errors comprises varying a modulation method of the modems for communicating the information corresponding to the information packets via the bidirectional communications path.

10. A method as claimed in claim **1**, wherein the second modem has a CSMA/CD interface, the method further comprising the step of communicating the information packets between the second modem and a second CSMA/CD path via the CSMA/CD interface of the second modem.

11. A method of communicating information packets to and from a CSMA/CD (Carrier Sense Multiple Access with Collision Detection) path via communication of information corresponding to the information packets over a bidirectional communications path, the information packets comprising upstream information packets and downstream information packets, the method comprising the steps of:

coupling a first end of the bidirectional communications path to a first modem, wherein the first modem is coupled to the first end of the bidirectional communications path via a first end interface;

communicating the information packets between the CSMA/CD path and the first modem via a CSMA/CD interface, wherein each of the information packets comprises a MAC-layer packet grouping of data that is grouped to fit into one MAC-layer packet of CSMA/CD networks, and wherein the half duplex communications are half-duplex with respect to MAC-layer packet groupings of data;

coupling a second end of the bidirectional communications path to a second modem, wherein the second modem is coupled to the second end of the bidirectional communications path via a second end interface;

communicating information corresponding to the downstream information packets and control information, for controlling operation of the second modem, from the first modem to the second modem via the bidirectional communications path;

changing direction of flow for the information corresponding to the information packets, the direction of flow changing based at least upon completion of communication associated with conveying information corresponding to at least one MAC-layer packet grouping of data across at least one of the first end interface and the second end interface; and

communicating information corresponding to the upstream information packets from the second modem to the first modem via the bidirectional communications path under control of the control information, the control information providing half duplex communications for at least the information corresponding to the information packets on the bidirectional communications path.

12. A method as claimed in claim **11**, wherein the step of communicating the information corresponding to the upstream information packets further comprises the step of enveloping information corresponding to at least one of the upstream information packets in at least one upstream information frame, the at least one upstream information frame further comprising at least one error check field for error checking of at least the enveloped information corresponding to least one of the upstream information packets, and wherein the step of communicating the information corresponding to the downstream information packets further comprises the step of enveloping information corresponding to at least one of the downstream information packets in at least one downstream information frame, the at least one downstream information frame further comprising at least one error check field for error checking of at least the enveloped information corresponding to at least one of the downstream information packets.

13. A method as claimed in claim **12**, and further comprising the step of including information relating to operation of the modems in at least one of the at least one upstream information frame and the at least one downstream information frame.

14. A method as claimed in claim **13**, wherein the information relating to operation of the modems comprises the control information from the first modem to the second modem and response information from the second modem to the first modem.

15. A method as claimed in claim **12**, and further comprising the step of communicating further frames between the first and second modems via the bidirectional communications path, each further frame comprising information relating to operation of the modems and an error check field for error checking of at least the information relating to operation of the modems.

16. A method as claimed in claim **15**, wherein the information relating to operation of the modems comprises the control information from the first modem to the second modem and response information from the second modem to the first modem.

17. A method as claimed in claim **11**, wherein information corresponding to one of the upstream information packets communicated between the modems via the bidirectional communications path comprises at least address, length, and data fields of a corresponding Ethernet frame communicated via the CSMA/CD path.

18. A method as claimed in claim **17**, wherein the information corresponding to one of the upstream information packets communicated between the modems via the bidirectional communications path further comprises a frame check sequence of the corresponding Ethernet frame communicated via the CSMA/CD path.

19. A method as claimed in claim **18**, wherein the information corresponding to one of the upstream information packets communicated between the modems via the bidirectional communications path further comprises a preamble and a start frame delimiter of the corresponding Ethernet frame.

20. A method as claimed in claim **11**, and further comprising the step of multiplexing signals of the first modem for communicating at least one of the information corresponding to the upstream information packets and the information corresponding to the downstream information packets between the first modem and a plurality of second modems.

21. A method as claimed in claim **11**, wherein the bidirectional communications path comprises a two-wire line.

22. A method as claimed in claim **11**, and further comprising the steps of:

monitoring errors in communicating at least one of the information corresponding to the upstream information packets and the information corresponding to the downstream information packets between the first and second modems via the bidirectional communications path, and

determining operations of the first and second modems in dependence upon monitored errors.

23. A method as claimed in claim **22**, wherein the step of determining operations of the modems in dependence upon monitored errors comprises varying a signal bandwidth of the modems for communicating at least one of the information corresponding to the upstream information packets and the information corresponding to the downstream information packets via the bidirectional communications path.

24. A method as claimed in claim **22**, wherein the step of determining operations of the modems in dependence upon monitored errors comprises varying a modulation method of the modems for communicating at least one of the information corresponding to the upstream information packets and the information corresponding to the downstream information packets via the bidirectional communications path.

25. A method as claimed in claim **11**, and further comprising the step of communicating the information packets between the second modem and a second CSMA/CD path via a second CSMA/CD interface.

26. A method of communicating Ethernet frames on a CSMA/CD (Carrier Sense Multiple Access with Collision Detection) path via communication of information corresponding to the Ethernet frames over a bidirectional communications path, the method comprising the steps of:

coupling the information corresponding to the Ethernet frames between the CSMA/CD path and a first modem via a CSMA/CD interface, wherein the first modem is further coupled to the bidirectional communications path via a first end interface; and

coupling the information corresponding to the Ethernet frames between the first modem and a second modem via the bidirectional communications path, wherein each of the Ethernet frames comprises a MAC-layer packet grouping of data that is grouped to fit into one MAC-layer packet of CSMA/CD networks, wherein the second modem is coupled to the bidirectional communications path via a second end interface, wherein the first and second modems are master and slave modems respectively, and the master modem controls the slave modem by control information communicated via the bidirectional communications path so that communications of at least the information corresponding to the Ethernet frames on the bidirec-

tional communications path take place in a half-duplex manner, wherein the half-duplex manner is half-duplex with respect to MAC-layer packet groupings of data, the half duplex manner of communications changing direction of flow for the information corresponding to the Ethernet frames, the direction of flow changing based at least upon completion of communication associated with conveying information corresponding to at least one MAC-layer packet grouping of data across at least one of the first end interface and the second end interface.

27. A method as claimed in claim **26**, wherein the bidirectional communications path comprises a two-wire line.

28. A method as claimed in claim **26**, wherein the bidirectional communications path comprises a two-wire telephone subscriber line and the modems communicate signals via the line at frequencies greater than telephone signal frequencies, the method further comprising the step of communicating telephone signals via the line.

29. A method as claimed in claim **26**, and further comprising the steps of monitoring errors in communicating the information corresponding to the Ethernet frames between the first and second modems, and determining operations of the first and second modems in dependence upon monitored errors.

30. A method of communicating information corresponding to information packets in both directions between a CSMA/CD (Carrier Sense Multiple Access with Collision Detection) path and a bidirectional communications path, the information packets being, the method comprising the steps of:

coupling the information corresponding to the information packets from the CSMA/CD path via a CSMA/CD interface to a first buffer, wherein the first buffer is coupled to the bidirectional communications path via a first end interface;

supplying the information corresponding to the information packets from the first buffer to the bidirectional communications path under control of a control unit, wherein each of the information packets comprises a MAC-layer packet grouping of data that is grouped to fit into one MAC-layer packet of CSMA/CD networks;

changing direction of flow for the information corresponding to the information packets, the direction of flow changing based at least upon completion of communication associated with conveying information corresponding to at least one MAC-layer packet grouping of data across at least one of the first end interface and the second end interface, the changing of the direction of flow being a characteristic of communications in a half duplex manner, wherein the half duplex manner is half-duplex with respect to MAC-layer packet groupings of data;

receiving the information corresponding to the information packets from the first buffer to the bidirectional communications path in a second buffer, wherein the second buffer is coupled to the bidirectional communications path via a second end interface;

coupling the information corresponding to the information packets from the second buffer to the CSMA/CD path via the CSMA/CD interface; and

producing in the control unit and supplying to the bidirectional communications path, or receiving from the bidirectional communications path and supplying to the control unit, control information, the control information communicated to provide that communications of the information corresponding to the information packets via the bidirectional communications path take place in the half duplex manner.

31. A method as claimed in claim **30**, wherein the information corresponding to the information packets and the control information are communicated via the bidirectional communications path as modulated signals, the method further comprising the steps of producing modulated signals for supply to, and demodulating signals received from, the bidirectional communications path.

32. A method as claimed in claim **11**, wherein information corresponding to one of the downstream information packets communicated between the modems via the bidirectional communications path comprises at least address, length, and data fields of a corresponding Ethernet frame communicated via the CSMA/CD path.

33. A method as claimed in claim **32**, wherein the information corresponding to one of the downstream information packets communicated between the modems via the bidirectional communications path further comprises a frame check sequence of the corresponding Ethernet frame communicated via the CSMA/CD path.

34. A method as claimed in claim **33**, wherein the information corresponding to one of the downstream information packets communicated between the modems via the bidirectional communications path further comprises a preamble and a start frame delimiter of the corresponding Ethernet frame.

35. A method of communicating information packets to and from a CSMA/CD (Carrier Sense multiple Access with Collision Detection) path via communication of information corresponding to the information packets over a bidirectional communications path, the method comprising the steps of:

coupling a first end of the bidirectional communications path to the first CSMA/CD path via a first modem coupled to the CSMA/CD path, wherein the first modem is coupled to the first end of the bidirectional communications path via a first end interface;

communicating the information packets between the CSMA/CD path and the first modem via a CSMA/CD interface;

coupling a second end of the bidirectional communications path to a second modem, wherein the second modem is coupled to the second end of the bidirectional communications path via a second end interface;

communicating information corresponding to the information packets between the first and second modems via the bidirectional communications path using half duplex communications controlled by the first modem, wherein each of the information packets comprises a MAC-layer packet grouping of data that is grouped to fit into one MAC-layer packet of CSMA/CD networks, and wherein the half duplex communications are MAC-layer half-duplex such that once information corresponding to a first MAC-layer packet grouping of data has begun to be transmitted into the bidirectional communications path the information corresponding to the first MAC-layer packet grouping of data is completely transmitted into the bidirectional communications path before information corresponding to a second MAC-layer packet grouping of data is allowed to begin to be transmitted into the bidirectional communications path; and

communicating control information for controlling the MAC-layer half duplex communications via the bidi-

rectional communications path from the first modem to the second modem.

36. A method as claimed in claim **35**, wherein the step of communicating the information packets using half duplex communications further comprises the step of enveloping information corresponding to at least one of the information packets in at least one information frame, the at least one information frame further comprising at least one error check fields for error checking of at least the enveloped information corresponding to at least one of the information packets.

37. A method as claimed in claim **35**, wherein information corresponding to one of the information packets communicated between the modems via the bidirectional communications path comprises at least address, length, and data fields of a corresponding Ethernet frame communicated via the CSMA/CD path.

38. A method as claimed in claim **35**, and further comprising the steps of:

monitoring errors in communicating the information corresponding to the information packets between the first and second modems via the bidirectional communications path,

and determining operations of the first and second modems in dependence upon monitored errors.

39. A method as claimed in claim **35**, wherein the second modem has a CSMA/CD interface, the method further comprising the step of communicating the information packets between the second modem and a second CSMA/CD path via the CSMA/CD interface of the second modem.

40. A method of communicating information packets to and from a CSMA/CD (Carrier Sense multiple Access with Collision Detection) path via communication of information corresponding to the information packets over a bidirectional communications path, the method comprising the steps of:

receiving a first information packet from the CSMA/CD path at a first modem via a CSMA/CD interface;

transmitting information corresponding to the first information packet on the bidirectional communications path in a first direction;

changing direction of communication of MAC layer groupings of information on the bidirectional communications path to a second direction that is opposite of the first direction, the direction of communication changing after the completion of transmission of the information corresponding to the first information packet;

receiving information corresponding to a second information packet from the bidirectional communications path at the first modem; and

transmitting the second information packet on the CSMA/CD path.

41. The method of claim **40**, wherein the first information packet is a first MAC layer grouping of information on the CSMA/CD path and the second information packet is a second MAC layer grouping of information on the CSMA/CD path, wherein the changing direction step further comprises:

operating the CSMA/CD interface to appear to MAC layer entities on the CSMA/CD path that MAC layer groupings of information are passed through the CSMA/CD interface and over the communications path in a half duplex manner with respect to MAC layer groupings of information.

42. The method of claim **41**, wherein the step of operating the CSMA/CD interface further comprises:

avoiding collisions on the bidirectional communications path of information corresponding to MAC layer groupings of information.

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United States Court of Appeals for the Federal Circuit

Ruckus Wireless, Inc., Cisco Systems, Inc. v. Innovative Wireless Solutions, LLC,
Nos. 2015-1425, -1438

PROOF OF SERVICE

I, Kimberly Jackson, being duly sworn according to law and being over the age of 18, upon my oath depose and say that:

I am a paralegal at Farney Daniels, PC, counsel of record for Defendant-Appellant Innovative Wireless Solutions, LLC.

On May 11, 2015, counsel has authorized me to electronically file the foregoing **Opening Brief of Appellant Innovative Wireless Solutions, LLC** with the Clerk of Court using the CM/ECF System, which will serve via e-mail notice of such filing to all counsel registered as CM/ECF users, including each of the following:

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Upon acceptance by the Court of the e-filed document, six paper copies will be filed with the Court, via overnight delivery, within the time provided in the Court's rules.

Date: May 11, 2015

/s/ Kimberly Jackson
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CERTIFICATE OF COMPLIANCE

This brief complies with the type-volume limitation of Federal Rule of Appellate Procedure 32(a)(7)(B), because it contains 4,744 words, excluding the parts of the brief exempted by Federal Rule of Appellate Procedure 32(a)(7)(B)(iii) and Federal Circuit Rule 32(b). This brief also complies with the typeface requirements of Federal Rule of Appellate Procedure 32(a)(5) and the type style requirements of Federal Rule of Appellate Procedure 32(a)(6), because it has been prepared in a proportionally spaced typeface using Microsoft Word 2010 in Times New Roman 14 point font.

Dated: May 11, 2015

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